Industrial QUALITY CONTROL

NOVEMBER, 1951 VOL. VIII, NO. 3

SQC Helps Forging Operations

AMERICAN SOCIETY FOR QUALITY CONTROL

Twice as much Usable Scale Length with a

SHEFFIELD COLUMN PRECISIONAIRE

MODEL NUMBER	MAXIMUM RECOMMENDED TOLERANCE	MINIMUM USABLE SCALE LENGTH BEYOND TOLERANCE LIMITS
1,000	.005	.0025
2,000	.0025	.0013
5,000	.001	.0005
10,000	.0005	.00025
20,000	.00025	.000125

7½ inches of usable scale length—*more than twice as much as most other air gages.*

MANY MORE CLASSIFICATIONS—more selections can be made because of the extra scale length—manufacturing tolerances can be widened to save time and cost without sacrificing quality.

SHOWS *HOW MUCH* PARTS ARE OUT—especially advantageous where parts are coming consistently on the borderline or just outside tolerance limits.

BETTER FOR BRINGING TO SIZE—Readings can be taken earlier when approaching size so that the operator is sure of not going beyond tolerance, in fact, he can accurately work to desired limits *within* the tolerance zone.

CLOSER MACHINE CONTROL—with greater scale length the trend of the machine and tooling to go out of control shows up sooner, reducing possibility of rejects.

MORE ACCURATE QUALITY CONTROL CHARTS—the column Precisionaire scale is a running quality control chart in itself. Readings can be transferred to a chart with greatest accuracy.

OPERATORS LIKE THE LONG SCALE—with higher amplifications the spread for the tolerance and each classification is wider, making the operator's job easier.

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GAGES • MEASURING INSTRUMENTS • MACHINE TOOLS • CONTRACT SERVICES • THREADING TOOLS

SQC IN THE CANTON FORGE DIVISION, FORD MOTOR COMPANY

STATISTICAL Quality Control, a precision tool for "on the job" usage by department supervision, job inspectors, and machine operators has proven its value at the Canton Forge Division of Ford Motor Company.

Die changes and repairs as well as machine adjustments can be anticipated accurately through proper analysis of Control Chart Data. In some cases operational changes or the elimination of an operation have been brought about by the proper use of the information provided in Quality Control Records.

Information gained on the Front Wheel Spindle Support Control Charts indicated that the hot pad operation was capable of holding tolerances equal to cold coin operations. With an inexpensive die change the cold coin operation was eliminated entirely on this forging. (See cover picture).

Scrap percentages were reduced materially on every job soon after Statistical Quality Control was placed on the job.

The Press Forging Department of the Canton Forge Division in a period of one year after the inauguration of Quality Control showed a marked reduction in rework and scrap due to dimensional variations, and down time for die repair was reduced by 30%. The average daily tonnage in this department was increased by approximately 20%, while the total man hours were reduced through operational improvements similar to the Spindle Support job.

Supervision has found Statistical Quality Control charts an invaluable training aid in assisting inexperienced personnel to gain the forging know-how required in the production of Ford's high quality forgings.

The X-bar and R chart with its code index provides a ready reference file on the unit's forging trend over a 24 hour period. Individual operators have been able to correct deficiencies in their methods and techniques by analysis of chart trends at shift change.

Members of management at Ford Motor Company, Canton, Ohio, feel that Statistical Quality Control as a new member of their productive team daily assists each department to prove the slogan, "YOU CAN PAY MORE, BUT YOU CAN'T BUY BETTER".

Industrial Quality Control

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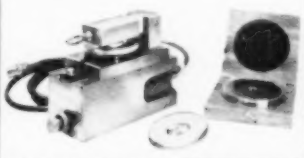

Custom-made fixture, employing Brown & Sharpe Gage Head Cartridge and one Amplifier, measures major and minor I.D.'s of tapered bores; indicates internal angle accuracy.

Brown & Sharpe Gage Head Cartridge and Electronic Amplifier

Here's a really practical basis for versatile precision gaging equipment at reasonable cost.

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It's the fastest thread gaging method ever devised

Nothing has ever before been offered that equals the inspection speed obtainable with this power thread gage. Just give a slight push on the handle — the gage is screwed into the work at *four revolutions per second*. Then reverse the pressure — the drive is immediately disengaged or the direction of revolution reversed.

Inspection is fast! . . . easy! . . . accurate! And at the end of the day the operator is still alert and fresh . . . yet frequently more than four times as many parts have been accurately checked as ever before.

It will pay you to write today for more information on this Taft-Peirce Power Thread Gaging Unit.

THE TAFT-PEIRCE MANUFACTURING COMPANY, WOONSOCKET, R. I.

T-P means Top Precision

Quality Control in Television Receiver Manufacturing

CARL L. GARTNER

Formerly Quality Control Manager, Television Receiver Manufacturing Division, Allen B. DuMont Laboratories, Incorporated

Organized Quality Control is fairly new in manufacturing operations. In even more recent years, the concept of quality control has evolved from a purely inspection function, designed for the purpose of screening out defectives, to an engineering program, calculated to aid in the manufacturing of a quality product economically and without re-work. Today, in many organizations the Quality Control operation is separate from the inspection groups. Consequently, Quality Control in these cases is concerned only with the procedural and specification aspects of inspection along with some statistics and reports, whereas the inspection groups will be handling the 100% and sampling inspection operations in the plant. More and more, however, the Quality Control organization is taking on the responsibility for the whole quality program—inspection, statistics, and procedures.

Manufacturing groups unfamiliar with such "new-fangled notions" as Quality Control invariably react unfavorably to the installation of statistical systems for Quality Control on the theory that "statistics don't work," and cannot correct defects. On the face of it, they are correct, but they overlook the primary fact that those who do the statistical work take and desire no credit for the corrective action. Rather, they are attempting to supply accurate information as to whether corrective action is indicated. Whether you call inspection Quality Control or visa versa, the fact remains that the action of inspection does not correct the error it brings to light.

Quality Control, by observation and use of reports from the various inspection groups, is able to ascertain trends and the causes for repeated failure to comply with specification. Whether or not this is the outcome of defective parts, defective workmanship, or defective methods, the information is analyzed and, after definitely ascertaining the cause, is referred to the proper persons for correction.

DuMONT RECEIVER QUALITY CONTROL ORGANIZATION

An example of a Quality Control organization, which I believe is taking advantage of all the latest principles in Quality Control techniques, is the one in operation at Allen B. DuMont Television Receiver Manufacturing Plant at East Paterson, New Jersey. The Quality Control organization in this case is divided into five groups: the Component Acceptance Section, the Incoming Inspection Section, the Production or Process Inspection Section, the Product Control Section, and the Inspection Equipment Facilities Section, with the necessary administrative group to handle supervision, statistical, engineering, and clerical aspects of the work.

Before discussing the activities of the various sections of the Quality Control Department, a word more on "Statistical Quality Control" would be in order. This particular title seems to have quite an ominous sound. Not every production man is a mathematician and the thought of applying formulas and figures to every phase of production activity is frightening. The truth of the matter is every man is something of a statistician. Most of us can average a column of figures, calculate the odds on a horse or even guess our chances of winning on a toss of a coin. Statistical Quality Control is the marriage of the science of averages and odds to the inspection function. Basically, statistical quality control has been applied at DuMont as a means of interpretation of the inspection results in order that 100% inspection may be kept at a minimum, and so that corrective action with regard to the process may be intelligently and rapidly consummated. There are two means of accomplishing this purpose: Analysis of the control charts which are applied to the inspection operations and sampling and acceptance procedures. The analysis of the control charts consists of reflecting to those responsible the existing status of quality and its variability so that action may be taken as required. Sampling inspection provides the procedure for doing inspection by sampling without the sacrifice of appreciable quality protection.

In the DuMont Television Receiver Plant the two techniques discussed above are widely used by all of the sections engaged in Quality Control activities.

The Receiver Quality Control Department has been set up, in general, to cover the three phases of quality control discussed previously; inspection, statistics and procedures. The purpose of the Department is one of positive insurance that the television receivers manufactured in the division are produced in accordance with the engineering specifications and the standard of performance and appearance laid down by the management of the company. Behind this is the real concern that the ultimate consumer will buy and enjoy DuMont television sets on their record and tradition of unexcelled quality. In order to preserve this integrity, Receiver Quality Control, hovers over every section and department of the division. It is organized on the premise that a disinterested observer, or someone not within the group struggling with a specific problem to be consummated within a scheduled time limit, is in a better position to "distinguish the trees from the forest."

DESIGN AND SPECIFICATION

In any preventative program it would be expected that the first point for inspection would be the incoming material, or the Incoming Inspection Section. However, there are several very important consid-

erations before material starts arriving in the manufacturing plant.

First, and most obvious of these, is Product Design, and in connection with this, it is evident that steps must be taken to incorporate into the design all the improvements which have been made available as a consequence of work on previous designs.

It is necessary to design with a knowledge of the tools and procedures of the assembly or manufacturing groups. It is essential that when the product is designed, the specifications for its performance are such as to result in a product which would perform satisfactorily in the field. That these same specifications be realistic from the standpoint of attainment in the factory is essential.

Because an engineer can fabricate in the laboratory one receiver which, let us say, may have a sensitivity of 25 uv* does not indicate that producing this receiver in manufacturing will result in mass production of 25 uv receivers. Tolerance on the characteristics of components, variations in gain of vacuum tubes, even the small variations in workmanship and adjustment in the factory, all may result in wide variations in production for this single important characteristic of the receiver. The wise engineer with the aid of proper statistical tools and experience should be capable of forecasting accurately the average and range of the measurements for these important characteristics.

In this connection considerable assistance is given to the designing group by the Receiver Quality Control Department. Here, during pilot runs on new models, continuous measurements are made on the important variables in the specifications. Averages and ranges of variability are plotted and these results referred back to engineering for review with regard to possible modifications of either the preliminary specifications or the design itself.

There is one rule which Receiver Quality Control must constantly observe—*the production and the specification must agree.* Accordingly, if it is found necessary to change the performance, appearance or assembly of production units, the specifications must be changed with it. If the production does not agree with the specification at any time, one or the other is wrong and must be changed.

*Refers to the 25 microvolt input signal required to obtain a 30 v pedestal to peak output signal at the grid of the cathode ray tube, as measured on an oscilloscope.

LOT BY LOT SAMPLING RECORD

PART No. 03001570

DESCRIPTION Cap, Pa, .005 mf 25% 600 V

VENDOR [redacted]

DEFECTS IN FIRST SAMPLE: Out of tol. in high side; Out of tol. in low; Wrong lead length; Pin holes in wax coating

SAMP. PLAN No. DR-7

SUMMARY PERIOD 3 mos.

	1949 YEAR DATE	REC. REPORT No.	LOT SIZE	FIRST SAMPLE SS.	FIRST SAMPLE DEF.	TOTAL SAMPLE SS1 + SS2 +	TOTAL SAMPLE TOTAL DEF.	Out of tol. in high side	Out of tol. in low	Wrong lead length	Pin holes in wax coating	INSPECTOR'S INITIALS	DISPOSITION OF LOT PASS, REJECT, ETC.	REMARK No.
1	8/15	0014	1000	35	0							TH	P	
2	8/25	0090	700	35	0							BK	P	
3	9/5	0170	1500	50	1	150	3	1				BK	R	1
4	9/20	0220	1800	50	1	150	2		1			CD	P	
5	10/5	0278	1250	35	1	105	1					TH	P	
6	10/22	0315	1155	35	2			1		1		BK	R	2
7	10/31		7405	240	5			2	1	1	1			3
8														
9	11-1	0407	1200	35	0							TH	P	
10	11/13	0438	1500	50	0							TH	P	
11	11/29	0500	2100	50	0							BK	P	
12	12/5	0539	2900	50	4			2		2		BK	R	4
13	12/10	0581	3500	75	0							TH	P	
14	12/17	0644	2700	50	0							TH	P	
15	1/8	0773	2006	50	1				1			TH	P	
16	2/1		15905	360	5									3
17														
18	2/3	0838	1550	50	0							CD	P	
19	2/21	0907	1275	35	0							CD	P	
20	3/3	0982	1475	50	0							TH	P	
21														
22														
23														
24														
25														

REMARKS
1. Returned to vendor
2. Rush- Balance of lot inspected.
3. Entered into summary report.
4. Rejection waived on lead lengths. 100% electrical inspection of lot.

Figure 1—**Lot-by-Lot Sampling Record**

This is a record of the inspection results obtained during sampling. Only first sample defectives are itemized to give good and bad lots equal weight in analysis of defect types. DR-7 is DuMont's plant designation for the JAN-STD-105 Double Sampling Plans, Inspection Level I, 0.5% AQL.

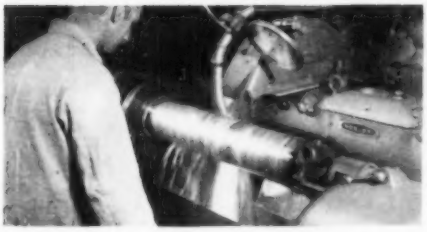
PROTOTYPE REVIEW AND TEST

After the engineering design of a new model is relatively complete, a number of prototypes of the new model are reviewed by Manufacturing and Receiver Quality Control Departments. Changes recommended by these departments to improve quality and simplify manufacturing operations are incorporated at this time. Subsequently, the field test truck, fully equipped with noise generating equipment, measuring instruments, portable antenna and power plants, and, of course, the new models, leaves for field tests. The results of this operation are checked by Engineering and Receiver Quality Control, and necessary changes are decided upon.

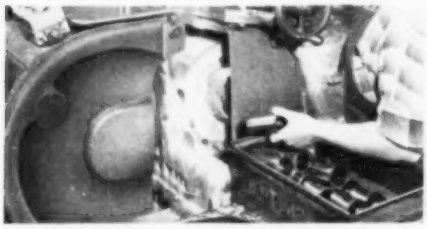
COMPONENT APPROVAL

Upon the completion of a design, the product will be specified by the Product Design Group. Based on a bill of materials, the Purchasing Department will be ready to start procuring these materials for production. At DuMont there is another quality step taken before the Purchasing Department may make any commitments for this bill of materials. This function is covered by the Component Acceptance Section of the Quality Control Department. It must make extensive tests on samples of all components, to be purchased from various vendors, which are specified for use in the product.

In Your Cylindrical or Centerless Grinding...



Grinding a large cylindrical part to exact tolerance and degree of finish. The Norton range of specifications enables you to select exactly the right wheel for work like this.



A plunge-cut grinding job to a shoulder on a centerless machine. Units being ground are textile machinery parts, for which wheels of Norton ALUNDUM* (fused alumina) in the correct grain size and grade, give best results.

Shaping a wheel by crush truing, with hardened steel crushing roll shown in raised position. Both Norton ALUNDUM and CRYSTOLON* wheels can be crush trued, to give excellent results in this rapidly growing method of grinding intricate O. D. contours.

QUALITY CONTROL is an important reason for Norton superiority. From the moment that the abrasives, bonds and other raw materials enter the mile-long Norton Worcester plant until the completed grinding wheels are shipped, quality control plays an important part in their manufacture. NORTON COMPANY, Worcester 6, Mass., distributors in all principal cities.

It's easier to

GET MORE UNITS

per dressing • per hour per wheel

WITH NORTON O. D. GRINDING WHEELS

Made by Quality Control

You want your cylindrical or centerless grinding wheels to deliver exactly the required tolerances and finish . . . in piece after piece . . . hour after hour . . . with a minimum of dressing or replacement.

With Norton wheels it's *easier* to get these results. Here are the reasons:

1. Norton Range of Specifications Covers All Your O. D. Jobs. Whatever your material or job specifications — in the complete line of Norton wheels for O.D. grinding you're sure to find the *one* wheel with the *right* combination of abrasive grain type and bond for top cutting performance and extra long wheel life — and Norton uniformity assures top performance in *every* wheel.

2. Norton Applicational Aid Covers Your Grinding Problems. In practically every case your Norton Distributor can quickly tell you which types of wheels you need. Backing him is the Norton Abrasive Engineer in your area. And behind both is the Norton technical staff, representing the resources and know-how of the world's largest manufacturer of abrasives.

3. Norton Stocks Cover Your Delivery Requirements. Your Norton Distributor keeps ample stocks of popular O.D. wheel types and sizes. Larger stocks are maintained in Norton warehouses in key cities throughout the country, and you can always count on prompt shipments from Norton Company's complete stocks in Worcester.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

NORTON
ABRASIVES

Making better products to make other products better

QUALITY HISTORY RECORD

1. Part No. 03001570 2. Used on [redacted]
3. Description Cap, Pa, .005 mF ±25% 600V
Usual Approximate
4. Lot Size Monthly Output
5. Sampling Layout No. DR-7
6. Vendor(s) [redacted]
7. Notes

8. Sampling Plan Applied D-7

Date		4-48	5-48
AQL	Maj.	0.5%	0.5%
	Min.		
AOQL	Maj.		
	Min.		
Inspection Level	Maj.	III	I
	Min.		
Type Inspection	Maj.	Normal	Reduced
	Min.		
UCL	Maj.		
	Min.		
LCL	Maj.		
	Min.		

DATE		MATERIAL RECEIVED		MATERIAL REJECTED		FIRST SAMPLE				
From	To	Lots	Items	Lots	Items	Total	Maj. Def.	% Def.	Min. Def.	% Def.
9	10	11	12	13	14	15	16	17	18	19
5-49	7-49	7	9325	1	3500	300	3	1.0		
8-49	10-49	6	7405	2	2655	260	5	1.9		
11-49	1-50	7	15705	1	2900	360	5	1.4		
2-50										

20. QUALITY CONTROL CHART

Per Cent Defective, Major
Per Cent Defective, Minor
Per Cent Defective

0 1.0 2.0 3.0

Figure 2—**Quality History Record**

This summarizes inspection results periodically so that Sampling Layout can be revised to Reduced Inspection when quality is good and to Tightened Inspection when quality is bad.

unless the parts have been previously tested and are on an approved list. It is only after approval by this section that a new component not previously approved from a given vendor, may be purchased.

INCOMING INSPECTION

The Incoming Inspection Section of the Receiver Quality Control Department must inspect all material which is purchased and which is to be used in the building of the product and determine whether it is or is not in accordance with the specifications. Incoming Inspection also has the responsibility of re-inspecting material from production and stores suspected of being defective. Material to be inspected is moved in and out of Incoming Inspection from a material hold area and is inspected either 100% or by a statistical sampling plan.* In most cases sampling plans are used because of the obvious economy and efficiency of the method.

A typical sampling layout specifies the sample size and the number of defectives permissible for any given lot size, for a particular component and from a particular vendor. If the quantity of defectives exceeds a permissible number, the entire lot is rejected. However, at times under the pressure of the requirement to meet schedules, rejected lots are in some cases detailed, i.e. 100% inspection is made in order to obtain the good material for the line; the effective savings of sampling plans in that case are confined to good lots. Sampling plan numbers are sent to the Purchasing Department in order that they may, when they choose, inform the vendor of the required quality level. "Lot by Lot" records are kept on all incoming material and a sample of this form is illustrated in Figure 1.

From these "Lot by Lot" records, a summary of the quality history of the vendor is compiled. (See Figure 2.) Purchasing bases future selection of vendors upon their respective quality histories. Incoming Inspec-

*JAN-STD-105 or MIL-STD-105A

CONTROL CHART FOR ATTRIBUTES

DESCRIPTION LINE #3 DATES INSPECTOR

DATE: 4-10 4-11 4-12 4-13 4-14 4-17

Upper Control Limit

Process Average

Lower Control Limit

Average defects per unit

UPPER CONTROL LIMIT = 0.78 PROCESS AVERAGE = 0.52 defects/unit LOWER CONTROL LIMIT = 0.13

Each point represents 20 units

Figure 3—**Control Chart for Teleset Assembly Line**

Out of control points on 4-10 and 4-11. Rapid corrective action resulted in the controlled condition shown from 4-12 on.

Johnson GAGE

QC

QUALITY · CONTROL

ATTRIBUTES

VARIABLES

External screw threads
And related specifications —
squareness and concentricity

Production and inspection control
statistical or standard
Attribute or variables sampling
plans, control charts,
and 100% inspection.

The proper gage to fit your
system and provide top results
with ease of operation
and minimum maintenance.

"FIXED" and "INDICATING" GAGES

JOHNSON GAGE COMPANY

BLOOMFIELD, CONN., U. S. A.

tion is responsible for the issuance of First Lot Approvals on all first receipts of any new part and/or vendor. When such is the case, more extensive testing is made and recorded on the component and involves Factory Engineering and the Component Acceptance Section. The results of these tests are distributed to the Engineering Department, the Factory Engineer and the Purchasing Department.

Close liaison between Incoming Inspection, Purchasing, and the vendor with regard to the quality of his deliveries and the sampling plan or procedure used, result in rapid improvement of the incoming material quality.

PRODUCTION INSPECTION

The Production Inspection Section of Receiver Quality Control has been divided into three subsections consisting of Process Inspection, Final Cabinet and Packing Inspection, and Final Acceptance Inspection. These groups are charged with the responsibility of inspecting and reporting on the quality of the actual workmanship in the factory. Here again it is important that inspection is not solely a screening process but is also the means for providing information to correct the process so defectives will not occur.

As in most assembly plants, much of the work is pre-fabricated and sub-assembled. The inspection of sub-assemblies is handled by means of Dodge-Romig single sampling plans wherever possible, but whether the material is checked 100% or a sampling plan is used, a control chart is kept. By this means the quality level of any sub-assembly is known at all times. As long as lots fall within the control limits, action is not taken. When out of control points occur, action is immediately taken with the responsible supervisor, and, if necessary, the factory engineer, to determine the assignable cause of the defect and make the necessary corrections. Particular lots in sub-assembly may necessarily require detailing by the inspectors when sampling plans indicate a high percentage of defectives. On the other hand, on many occasions it is possible to return the entire lot to the manufacturing group responsible, for detailing by them, which has more salutary results. The Production Inspection Section is also responsible for the inspection of the television chassis on each of the three 465 foot

Figure 4—**Chassis Assembly Lines at DuMont**

Note the quality control board on the overhead bridge at the end of each line showing the previous day's quality and whether current quality is in or out of control.

long belt conveyor assembly lines. Checker repair positions are maintained by manufacturing at various points along these lines. Defectives found by these checkers are immediately reflected to the production operators. The actual line inspection, however, takes place at the end of each line where 100% inspection is maintained under the supervision of Receiver Quality Control. Defectives found in these positions are noted on an inspection log sheet and a control chart is maintained as il-

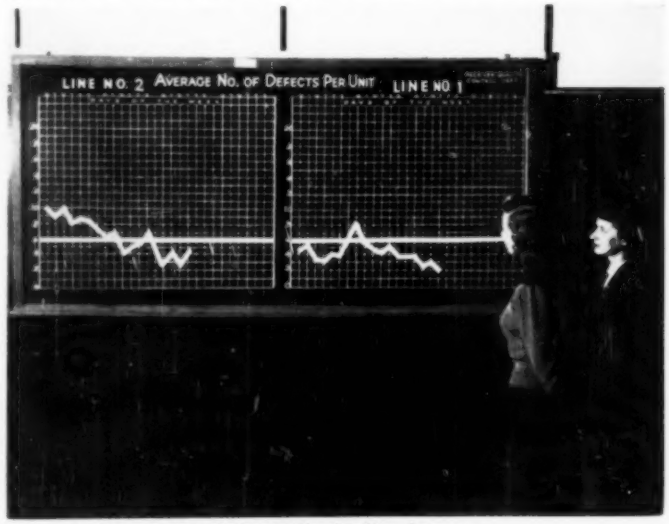
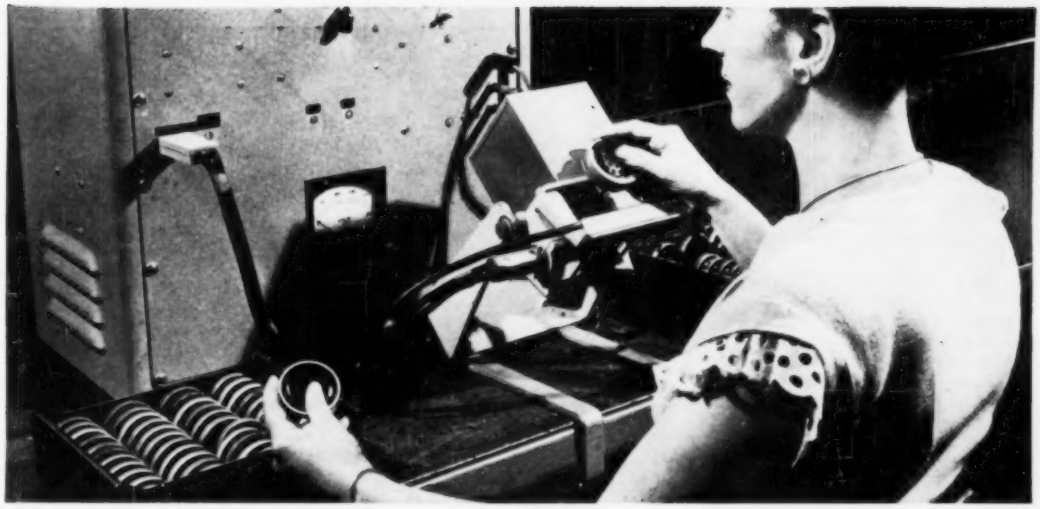


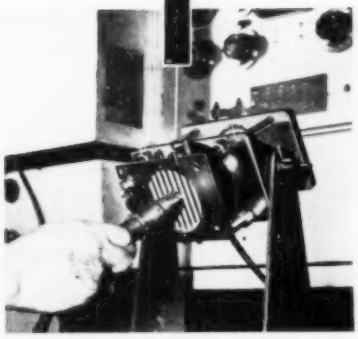
Figure 5—**Control Boards for Daily Quality Average**

These are placed at the head of each line where they can be seen readily by assembly personnel.



This Western Electric employee mounts a transmitter in the test fixture which is swung down to face an artificial mouth at 45-degree angle, just as transmitters are held in use. More than a million transmitters are tested each year.

This mouth speaks to millions



At Bell Laboratories a scientist employs a condenser microphone to check the sound level from another type of artificial mouth, used in transmitter research.

To serve the changing needs of telephone subscribers millions of telephone sets have to be moved each year. Before being put back into service most of them are returned to the Western Electric Company's Distributing Houses where they receive a thorough checkup.

Western Electric engineers needed a rapid method of testing transmitters over a range of frequencies. At Bell Telephone Laboratories, scientists had just the thing—a technique they had devised for fundamental research on transmitters. In co-operation with these scientists, Western Electric engineers developed the practical tester in the illustration.

The transmitter is removed from the handset and put in front of an artificial mouth which emits a tone that swings several times per second over a band of frequencies. A signal lamp tells whether the transmitter is good. Each test takes 5 seconds.

This new tester illustrates how Bell Laboratories research and Western Electric manufacturing skill team up to maintain your telephone service high in quality yet low in cost.

BELL TELEPHONE LABORATORIES

• EXPLORING AND INVENTING, DEVISING AND PERFECTING, FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE

lustrated in Figure 3. Approximately every 30 minutes the information with regard to the line position responsible for the defect is routed back to the proper supervisor or group leader on the main line in order that corrections may be made without delay. Here again, if the chart remains in control no particular action is taken. However, the upper and lower control limits on the chart are shifted every week, based on the previous week's attained average, and if the line workmanship improves, the average becomes better and better. Consequently, items which previously could not throw the chart out of control, in the latter stages of production, would be significant out of control points. In this manner corrective action is taken on the basis of high spots until the whole process is shaken down to its "grass level" of quality.

Sets found defective by these final chassis inspectors are tagged and subsequently repaired by manufacturing, re-inspected and routed to the electrical test section. The inspectors on each of the lines are considered an inspection group and are supervised by group leaders reporting to the Process Inspection foreman who in turn reports to the Process Inspection Section Head. The morale and promotional aspects of quality are not overlooked, particularly on the main line. Here, where the bulk of the operators are located, is the best proving ground for a quality campaign. Over each of the main lines have been suspended large boards on which removable numbers indicate the previous day's attained qaulity level in terms of defects per unit. These light boards may be seen in the photograph in Figure 4. Each board has a red or amber light to show whether the particular line's present defect level is or is not out of control. By this means the line operators get a continuous picture of the line quality and the line operators compete between lines for quality instead of quantity. Quantity is governed automatically by the speed of the conveyors. In addition, large boards in the form of graphs are kept at the beginning of each line and are enlargements of the control chart results on each line. The photograph in Figure 5 illustrates their use in the factory.

Process Inspection has the additional responsibility of inspecting excess materials from the main lines or from sub-assemblies being returned to stores in order to ascertain whether it is the correct prime material under the proper part number.

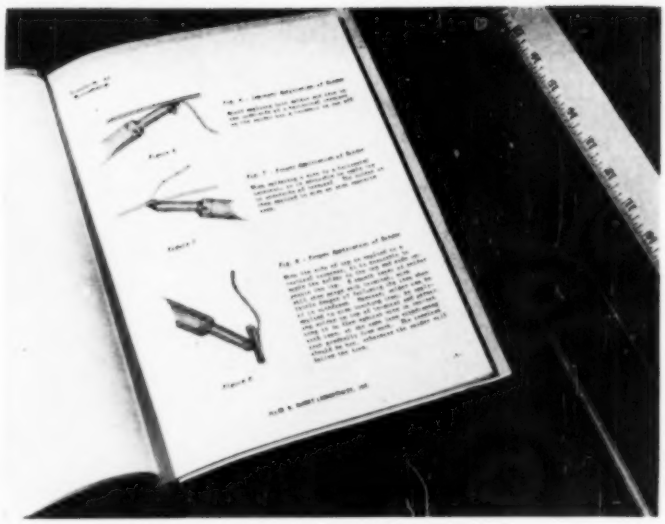


Figure 6—**Typical Page in the DuMont Soldering Manual**

Carefully prepared procedures and specifications have been issued by the Quality Control Department to all inspection and manufacturing groups covering some of the most subjective quality characteristics. A company manual on soldering and wiring techniques (Figure 6) has played an important part in this program. A similar manual for procedures and statistical sampling, including the necessary tables, has been prepared for Incoming Inspection personnel, is used by the Purchasing Department, and is often forwarded to vendors.

FINAL ACCEPTANCE INSPECTION

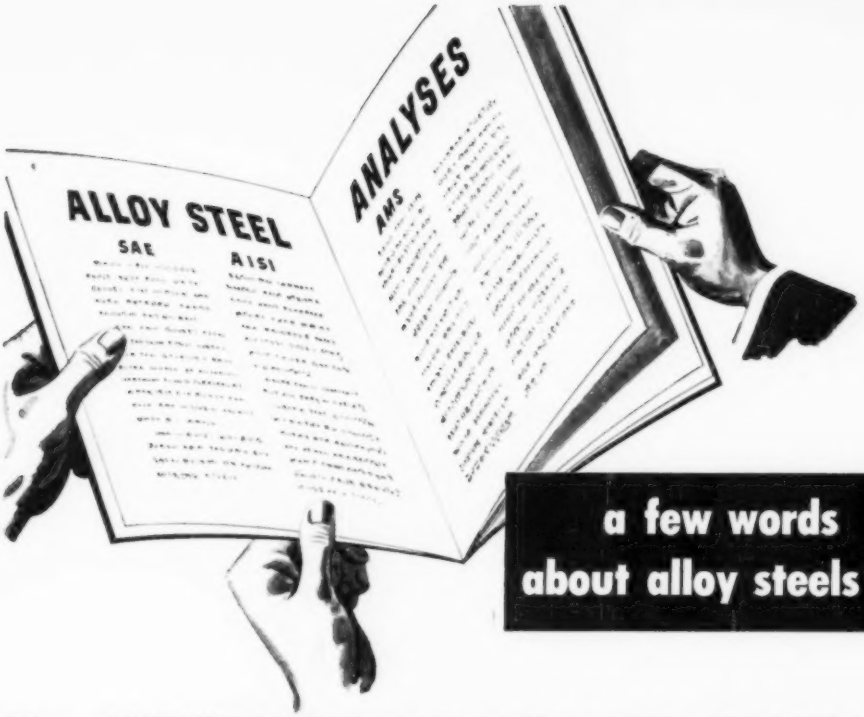
The Production Inspection Section is also responsible for the Final Acceptance Inspection operation. In this operation, completed television chassis which have been processed through the Electrical Test Section of manufacturing and installed in cabinets in Final Cabinet Assembly, are checked for all their operational characteristics by men working on spurs of the Final Cabinet Assembly roller conveyor in partially sound insulated booths. These inspectors usually work in two man teams. One man sets up the picture and checks all of the rear controls on the chassis. The other, usually called the front man, actually operates the receiver and checks its performance with regard to picture quality, noise, calibration of the dial, ease of operation of the controls, sound quality, tuning eye deflection, linearity of the picture and numerous other characteristics of the set.

Passing this inspection, the receiver continues down the line for cabinet touch-up, Final Cabinet and Packing Inspection and into packing. Both the final electrical inspectors and the final cabinet inspectors report to inspection foremen who in turn report to the Production Inspection Section Head.

Control Chart techniques are used in Final Acceptance Inspection, and on the information contained in these control charts, the factory engineers act to reduce causes of defects. Management, Engineering, Manufacturing and others are apprised daily of the major defects and what remedial steps have been taken. The inspector's log sheet, indicating the nature of defects and the percentage of production found defective, is examined twice an hour by the Final Cabinet Assembly foreman and the factory engineer in order that the operations can be corrected without undue loss of time.

PRODUCT CONTROL SECTION

The Product Control Section of Receiver Quality Control is a group



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which inspects and tests completely on a sampling basis and has been set up to examine the product and/or the process at various key points in the cycle of design and production against the engineering specifications. During the pilot run, Product Control technicians, in their laboratory, examine every unit using an abbreviated form of type test in order to supply Engineering with information with regard to averages and ranges of measurements on the electrical specifications. On the basis of these measurements, Engineering is able to review specifications or the design. It is the Product Control technicians who make the necessary field tests on the engineering and pilot run models which were discussed earlier in this article. Product Control is also responsible for making packing, shipping, heat and humidity and various other tests of extensive nature which are normally confined to a limited number of units. Product Control also makes a sampling inspection between the main chassis assembly line and the electrical test section to check the quality of the output of the main lines' assembly and 100% inspection. Daily and weekly reports and control charts are maintained for this operation.

TYPE TESTING

The electrical test and alignment are all part of the manufacturing operation. Subsequent to test and alignment, Product Control makes an inspection with regard to certain engineering specifications on a fairly large sampling. The particular specifications which are examined are determined as a consequence of the type testing of a limited number of chassis taken from this same point and brought to the Quality Control Laboratory. Indications of trends, with regard to any point in the specifications, found significant in type test are referred to the Product Control inspector after test, who then for a period of time concentrates on this characteristic until his measurements indicate the item is under control or necessary corrective action has been successful if lack of control was indicated.

Results of both the type tests and the concentrated sample tests are forwarded to the various departments concerned and may indicate action by the Engineering Department.

Figure 7—**Extended Life Test in Progress on Fifty Receivers**

These tests yield data on failures during operation. Sets are automatically cycled three hours on and one hour off to duplicate realistically actual operation.

LIFE TEST LABORATORY

Product Control also takes samples from Finished Stock daily. These samples are taken to the Life Test Laboratory where they are given a consumer's acceptance inspection and rated in demerits according to seriousness; after this inspection they are put on accelerated life tests. A life test of a number of chassis may be seen in operation in Figure 7. The duration of these life tests is varied from time to time in order to gain the maximum advantage from this operation. The sets are then rechecked after life test and reports on the results of these tests forwarded to the proper persons.

FACTORY ENGINEERING

Factory Engineers have been mentioned frequently in this article. This arm of the manufacturing organization makes possible the most effective step of all: to isolate the causes of defects and make permanent correction. It is the responsibility of this group to institute immediate remedial measures, temporary and permanent. The problems as highlighted by the control charts are instantly and automatically spotted by the factory engineer assigned to the location in question. Receiver Quality Control gets reports from the Factory Engineer as to the progress made in each particular matter and if progress is not reported, these matters are followed up with him. Furthermore, the division manager who is in receipt of all the information on the inspection reports and control charts will personally follow up both Receiver Quality Control and Factory Engineering when any type of defect or operation remains out of control unduly long.

INSPECTION EQUIPMENT FACILITIES SECTION

The last of the sections under Receiver Quality Control Department is the Inspection Equipment Facilities Section which is responsible for the design and construction of simple jigs and fixtures for test purposes, the maintenance and calibration of instruments used by Receiver Quality Control, and the monitoring of the Standard Signals used for receiver tests.

CONCLUSION

Basically the whole Quality Control organization at DuMont has been imbued with the prime concept that it is not their function to merely prevent defective material from arriving in the plant or being shipped in the finished product, although this insurance must be guaranteed, but to

report accurately as to the nature of the defects in order that the vendors, processes, or designs may be adequate from a quality point of view. Continuously, defects attributable to components are reviewed, specifications are improved, and corrective action taken with close vendor liaison. It is essential that any defect be analyzed as to its basic cause if such a program is to be successful. The unending belief in this theory has resulted in a Quality Control organization that operates economically, and by the process of passing along the proper information to Manufacturing, the manufacturing process becomes more and more economical. The results are passed along to the consumer in maximum value for his television dollar.

Variations in Conventional Control Charts

CARL E. NOBLE

Kimberly-Clark Corporation

THE chemical processes in the paper industry offer an opportunity for the application of a number of interesting variations of the conventional quality control charts. These variations are necessitated by the normal shifts in process averages and the stratifications inherent in certain paper-making operations. This discussion cites examples in which the standard procedures for calculating control limits yield too narrow or too wide limits and describes satisfactory procedures to employ in such cases. Techniques for obtaining the most efficient method of sampling various paper processes are also presented.

THE FUNCTION OF THE CONTROL CHART

One of the first steps connected with the installation of a control chart on a certain process is that of establishing the size of the subgroup from which the items in the sample are to be selected. The subgroup for an hourly control chart on a machine may be all of the items produced by the machine during the hour. The sample is selected at random from the hour's production. In other cases the subgroup and the sample are composed of one and the same set of n items taken in succession from the process. Regardless of the subgroup, the control chart tests the variability in the process from subgroup to subgroup in relation to the process variability within the subgroup. Control charts based upon samples of n consecutive items have served valuably for process control and in directing attention to certain assignable causes for extreme variation in some of the paper manufacturing operations.

However, it is not always feasible to eliminate these assignable causes because (a) there is often lacking the knowledge necessary to eliminate them, or (b) the effects of these causes upon the quality of the product are not sufficient to make their elimination financially worthwhile. One is therefore forced to consider these known assignable causes as part of the normal operation. The function of the control chart in these situations is to detect the presence of assignable causes normally nonexistent in the process; that is, those outside and beyond the assignable causes which have been identified and accepted as part of normal operation.

AN EXAMPLE

A type of problem often confronting the quality control engineer in the paper industry will be presented for illustration. The engineer wishes to inspect incoming cars of clay for brightness and to maintain control charts on this quality characteristic of the clay. Clay is an important component in the mixture used in coating paper. At the present time he selects four beakers of clay at random from each car as it is unloaded. Three pellets are prepared in a standard manner from the clay in each beaker, and one brightness measurement is made on each pellet. Thus, twelve brightness measurements are obtained on the sample from each car. The values shown in Table 1 are typical of the measurements for one car, where the y's are the averages of the three measurements within a beaker.

The problem is to find control chart limits for the average, $\bar{y}$, of the twelve brightness measurements in the sample and to obtain a method of testing the variability of the clay within the car. It may be observed that the twelve measurements in Table 1 are not independent random measurements. The measurements on pellets from the same beaker do not appear to vary as greatly as the measurements on pellets from different beakers. There is stratification within the sample. When stratification exists within the sample, as

TABLE 1—**Brightness Measurements on Clay**

	Beaker 1	Beaker 2	Beaker 3	Beaker 4
	81.1	81.5	80.6	80.2
	81.6	81.7	80.5	80.0
	80.9	81.9	80.1	80.7
Averages y	81.2	81.7	80.4	80.3
Grand Average, all four beakers: $\bar{y} = 80.9$				

it does between beakers in this case, sets of twelve measurements such as those in Table 1 cannot be considered homogeneous random observations. Hence, the use of the range or standard deviation of the twelve measurements is not sound, and one should not set control limits for samples of size twelve using the conventional formulas $\bar{X} \pm A_2\bar{R}$ (or $A_1\sigma$) and $D_3\bar{R}$ and $D_4\bar{R}$ (or $B_3\sigma$ and $B_4\sigma$), since these formulas assume homogeneous data.*

If the twelve measurements were considered as independent random measurements and a control chart for averages were set up on the basis of groups of twelve such measurements by the conventional formulas for homogeneous samples, the control limits would be too narrow. In the extreme case where there is no variability within the beakers, the average $\bar{y}$ of the twelve measurements fluctuates as an average of four independent measurements because there then exists the equivalent of only four measurements. Taking more than one measurement within a beaker in this case fails to increase the precision of the $\bar{y}$ value.

What then is a proper approach to use in such situations? A practical approach involves, first, the calculation of the average of the three measurements within each beaker. The averages will be called y_1, y_2, y_3, and y_4 for Beakers 1, 2, 3, and 4 respectively. These averages are independent random values. Hence, the conventional formulas apply if the samples are considered to be made up of four such y values rather than the original twelve measurements. The average, $\bar{y}$, and the range, R_y, of the y's in Table 1 are 80.9 and 1.4 respectively.

A number of cars of clay have to be inspected, with the inspection results exhibiting some degree of control, before these results are used in setting control limits. For the sake of simplicity, it will be assumed that inspection data from twenty cars have shown control and that the average range $\bar{R}_y$ of the R_y's is 1.50. The standard value, $\bar{y}'$, of the $\bar{y}$'s is taken as 80.00. The control limits are $\bar{y}' \pm A_2\bar{R}_y$ for $\bar{y}$ and $D_3\bar{R}_y$ and $D_4\bar{R}_y$ for R_y, where A_2, D_3 and D_4 are based on a sample size of four. Therefore, the control limits for $\bar{y}$ in this problem are

$$\text{UCL} = 80 + (0.729)(1.50) = 81.09$$
$$\text{LCL} = 80 - (0.729)(1.50) = 78.91.$$

The central line for the R_y chart is $\bar{R}_y$, or 1.50, and the control limits for this chart are

$$\text{UCL} = (2.282)(1.50) = 3.42$$
$$\text{LCL} = (0)(1.50) = 0.$$

The R_y chart serves as a check on the between-beaker variability.

The ranges, R, of the three measurements within the beakers may be used for controlling the within-beaker variability. These within-beaker ranges in Table 1 are 0.7, 0.4, 0.5 and 0.7 for Beakers 1, 2, 3, and 4 respectively. If the within-beaker ranges for the twenty cars mentioned above show satisfactory control and average 0.50, then the control limits for these R's are

$$\text{UCL} = D_4\bar{R} = (2.574)(0.50) = 1.29$$
$$\text{LCL} = D_3\bar{R} = (0)(0.50) = 0$$

when D_3 and D_4 are based on a sample of size three. These R values are logged but are generally not charted. If a range is greater than 1.29, it is circled and proper action is taken. A significantly high range is often due to faulty testing.

A CHECK ON THE EFFICIENCY OF THE SAMPLING PROCEDURE

In the problem described above, four beakers of clay are selected at random from the car and three brightness measurements are made on the clay from each beaker. Does the described method of sampling and testing provide the most precise estimate of the average brightness of clay in each car for the time and effort expended? In order to answer this question, it is necessary to obtain estimates of the between-beaker variance component, σ_b^2, and the within-beaker variance component, σ_w^2, of the brightness measurements. These values could be obtained rather easily by the analysis of variance technique. In order to by-pass the usual analysis of variance approach, σ_w^2 and σ_b^2 are calculated in the following manner. An unbiased estimate of σ_w^2 is found by averaging the variances σ^2 of the individual measurements within the beakers, where each σ^2 is the sum of the squares of the deviations of the individual measurements within a beaker from their average, divided by one less than the number of such measurements. For Beaker 1 in Table 1,

$$\sigma^2 = [(81.1 - 81.2)^2 + (81.6 - 81.2)^2 + (80.9 - 81.2)^2]/2 = 0.13.$$

Four such σ^2 values are obtained, one for each of the four beakers from each car. The average σ_w^2 of the eighty σ^2 for the twenty cars mentioned above may be assumed to equal 0.09.

The next step involves calculating the variance, σ_y^2, which equals the sum of the squares of the deviations of the four y values from their average $\bar{y}$, divided by one less than the number of y values. For the measurements in Table 1,

$$\sigma_y^2 = [(81.2 - 80.9)^2 + (81.7 - 80.9)^2 + (80.4 - 80.9)^2 + (80.3 - 80.9)^2]/3 = 0.4467.$$

It may be assumed that the average $\bar{\sigma}_y^2$ of these variances for the twenty cars is 0.54. Since there are three measurements within each beaker, the between-variance component σ_b^2 is found by applying the formula,

$$\sigma_b^2 = \bar{\sigma}_y^2 - \sigma_w^2/3$$
$$= 0.54 - 0.09/3$$
$$= 0.51.$$

The variance $\sigma_{\bar{y}}^2$ of the average of the twelve measurements for each car is given by the formula

$$(1) \qquad \sigma_{\bar{y}}^2 = \sigma_w^2/12 + \sigma_b^2/4$$

when twelve individual measurements are made on clay from four different beakers as in the previous case. Thus,

$$\sigma_{\bar{y}}^2 = 0.09/12 + 0.51/4$$
$$= 0.135.$$

Hence, the 3σ control limits for the $\bar{y}$ chart are

$$\bar{y} \pm 3\sigma_{\bar{y}} = 80.00 \pm 3\sqrt{0.135}$$
$$= 80.00 \pm 1.10$$
$$= 78.90 \text{ and } 81.10.$$

These limits are essentially the same as those obtained before.

What are the control limits for the $\bar{y}$ chart if five beakers of clay are selected at random from each car and brightness tests made on but one pellet from each beaker? The value of $\sigma_{\bar{y}}^2$ in this case is estimated to be

*The constants A_1, A_2, B_3, B_4, D_3 and D_4 as listed here, as well as d_2 mentioned later in the paper, are defined in reference [1].

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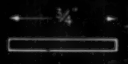
5 DIMENSIONS
2000 PER HOUR

5 DIMENSIONS
3600 PER HOUR



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(2) $\sigma_{\bar{x}}^2 = (0.09)/5 + (0.51)/5 = 0.120.$

Both components of variance, σ_b^2 and σ_w^2 are divided by five because five individual tests are made on clay from five beakers, one test on each beaker. This sampling procedure gives a more precise estimate of the average brightness of clay in each car than does the one previously mentioned. The question then arises as to which sampling procedure is the easier. One must weigh the time required to take five rather than four beakers of clay from each car against the time required to prepare and test twelve pellets rather than five. Generally, the selection of five beakers of clay from each car is the more efficient. If this procedure is selected, then each of the five measurements in a car can be considered as independent and random measurements. Hence, the conventional formulas for obtaining the control chart limits for both average and range are applicable, just as though there were no stratification.

A SECOND EXAMPLE

As a second example, the problem of setting up a control chart for aiding in the hourly control of the stretch in a certain creped paper which is manufactured in rolls will be considered. The manufacturing process is such that it is possible to select paper for testing at only four distinct positions within a roll. However, the stretch at these positions acts as though the positions were randomly selected within the roll.

Since thirty to forty minutes are required to manufacture a roll, it is impractical for the subgroups over which the hourly sample is taken to be greater than one roll. It is also reasonable to expect corrective action between rolls when action is necessary. An investigation over a period of two months revealed that under normal operations the variance, σ_w^2, within a group of stretch measurements all made upon paper at one position in the roll was approximately 20, while the variance, σ_b^2, between such groups within a roll was approximately 15. The stretch data both within a position and between positions within a roll may be assumed to be normally distributed. Since it is desired to establish an $\bar{X}$ control chart in which the $\bar{X}$ values are based upon a sample of size four, there are three likely sampling procedures. There

TABLE 2—**Tensile Readings on Two Types of Paper**

	Type A					Type B					Combined Samples	
Hour	X_1	X_2	X_3	$\bar{X}$	R	X_1	X_2	X_3	$\bar{X}$	R	$\bar{X}_6$	R_6
1	17	19	18	18.00	2	26	20	24	23.33	6	20.67	9
2	23	19	19	20.33	4	23	25	21	23.00	4	21.67	6
3	22	22	22	22.00	0	23	24	22	23.00	2	22.50	2
4	19	21	18	19.33	3	24	23	24	23.67	1	21.50	6
5	22	18	19	19.67	4	21	22	24	22.33	3	21.00	6
6	19	20	18	19.00	2	22	19	21	20.67	3	19.83	4
7	21	17	25	21.00	8	24	23	23	23.33	1	22.17	8
8	19	17	22	19.33	5	25	24	23	24.00	2	21.67	8
9	20	20	21	20.33	1	20	23	24	22.33	4	21.33	4
10	20	21	19	20.00	2	25	19	25	23.00	6	21.50	6
	Average			19.90	3.1	Average			22.87	3.2	21.38	5.9

can be obtained (a) four measurements on an area of paper cut from one position randomly selected from the four possible positions within the roll; (b) two measurements on paper cut from each of two positions selected at random from the four possible positions; (c) one measurement on paper cut from each of the four possible positions within the roll. If procedure (a) is applied, the variance, $\sigma_{\bar{x}}^2$, of the mean of the four measurements in the sample is given by the formula,

(3) $\sigma_{\bar{x}}^2 = 20/4 + 15 = 20.$

The 3σ limits in units about a standard of 40 units are $40 \pm 3\sqrt{20}$, or 40 ± 13.4. If procedure (b) is applied,

(4) $\sigma_{\bar{x}}^2 = 20/4 + 15/2 = 12.5.$

The 3σ limits are then $40 \pm 3\sqrt{12.5}$ or 40 ± 10.6. Finally, for procedure (c),

(5) $\sigma_{\bar{x}}^2 = 20/4 + 15/4 = 8.75,$

and the 3σ limits are $40 \pm 3\sqrt{8.75}$ or 40 ± 8.9. Procedure (c) lends considerably more sensitivity to the control chart and should be adopted providing the added sensitivity outweighs the extra difficulty of sampling the roll at four positions rather than at one or two positions.

In this problem it was advisable to install procedure (c). However, both procedures (a) and (b) have been found more practical in other similar problems. For example, if the specifications are sufficiently wide, approach (a) may be sensitive enough to maintain satisfactory control of the process. The use of procedure (a) may also be advisable when it is necessary to stop production in order to sample at each position.

These are only two of the many examples which could be cited from the paper industry to show the values gained by studying the variances inherent in the sampling and testing systems. Many others could have been mentioned. For instance, could as much information be obtained by preparing only two rather than three pulp hand sheets and taking more brightness readings on each hand sheet in order to estimate the average brightness of a batch of pulp? Or, is it a waste of time to take more than two brightness tests per hand sheet? These questions can be answered by securing reliable estimates of the within and between sheet variances. The establishment of control charts for checking testers frequently involves these techniques. This approach also plays an important part in the design of experiments conducted in numerous paper-making processes.

THE SUBGROUP DIVIDED INTO WELL DEFINED STRATA

In the previous discussion, the subgroup was not considered to be divided into well defined strata. The beakers of clay or positions in the rolls were selected from an almost endless number of possible beakers in the car or positions in the roll. In contrast to this situation there often exists a finite number of strata, such as machines and rolls, to be included in a subgroup. The proper procedure to follow in the calculation of control chart limits with a finite number of strata in the subgroup is often quite different from that described above, when there exists an infinite number of strata in the subgroup. To gain an insight

into the problem, see Hansen and Hurwitz [2]. This reference states that if there are K strata each of size N within the subgroup with σ_w^2 and σ_b^2 being the average variance within and between the K strata and n (n = N) items are randomly selected from each of k randomly selected strata (k = K), then the variance, $\sigma_{\bar{x}}^2$, of the sample mean is given by the formula:

$$(6) \qquad \sigma_{\bar{x}}^2 = \left(\frac{KN-kn}{KN-1}\right)\left(\frac{\sigma_w^2}{kn}\right) + \left(\frac{K-k}{K-1}\right)\left(\frac{\sigma_b^2}{k}\right).$$

As the number of strata, K, approaches infinity, the factors (KN-kn)/(KN-1) and (K-k)/(K-1) each approach unity. Formula (6) becomes

$$(7) \qquad \sigma_{\bar{x}}^2 = \sigma_w^2/kn + \sigma_b^2/k.$$

Formulas (1)—(5) are special cases of this formula. If n items are randomly selected from each of the K strata (that is, k = K), then the influence of σ_b^2 upon $\sigma_{\bar{x}}^2$ is eliminated. Formula (6) becomes:

$$(8) \qquad \sigma_{\bar{x}}^2 = \left(\frac{KN-kn}{KN-1}\right)\left(\frac{\sigma_w^2}{kn}\right).$$

When the number of items, N, in each stratum approaches infinity, formula (8) simplifies to

$$(9) \qquad \sigma_{\bar{x}}^2 = \sigma_w^2/kn.$$

An example will now be presented in which formula (9) applies.

AN EXAMPLE IN STRATIFIED SAMPLING

Many operations, beginning with the woodland's operations, play a part in the preparation of "pulp furnish" before this pulp furnish is sent over the paper machine to be formed into a continuous sheet of paper. The following example concerns a pulp furnish prepared in one system of operations and sent over two different paper machines. The tensile strength of Type A paper produced on the first machine is supposed to average 20 units, while the tensile strength of Type B paper produced on the second machine is supposed to average 23 units. By adjusting the machines differently, it is possible to get the difference of three units in tensile strength of the two types of paper even though the machines are supplied pulp furnish from the same system. From each of

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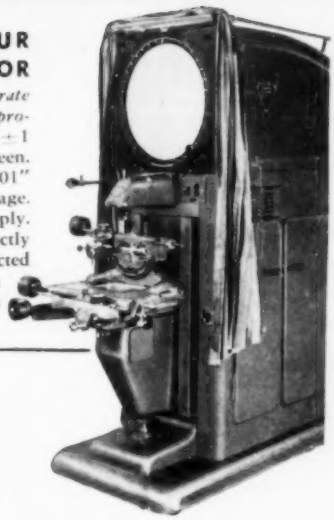

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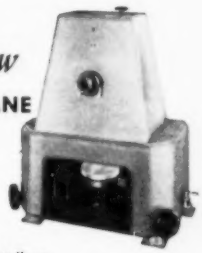

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the machines, three specimens of the paper are selected hourly and tested for tensile strength. Table 2 exhibits the measurements for ten hourly samples of size three from each machine.

At least 100 such hourly samples would generally be collected before setting up control charts and testing the process for control. However, for the sake of simplicity the number of samples is limited to ten in this example. Since the average ranges of the tensile strength measurements for the two types of paper are not significantly different (they are expected to be approximately the same), the average ranges $\bar{R}$ will be assumed identical and equal to 3.15, which is the average of the two calculated $\bar{R}$'s. The standard values, $\bar{X}'$, will be taken as 20 and 23 for Type A and Type B paper respectively. Then for the Type A paper, the control limits for $\bar{X}$ are,

$$\bar{X}' \pm A_2\bar{R} = 20 \pm (1.023)(3.15) = 20 \pm 3.22,$$

or 16.78 and 23.22.

For Type B paper, the control limits for X are,

$$\bar{X}' \pm A_2\bar{R} = 23 \pm (1.023)(3.15) = 23 \pm 3.22,$$

or 19.78 and 26.22. For both types of paper, control limits on the R charts are,

$$D_3\bar{R} = 0 \text{ and}$$
$$D_4\bar{R} = (2.574)(3.15) = 8.11.$$

Figure 1 exhibits these control charts.

If the tensile strength of the paper is too high or too low, the cause may be due to the machine or to the pulp furnish. In order to get a more sensitive control for the influence of the pulp upon the strength, the hourly tensile strength measurements for Type A and Type B paper are combined. A control chart for the averages $\bar{X}_6$ of the six hourly tensile strength measurements is constructed. This is a problem in stratified sampling in which all strata are sampled. Hence, the variance of the average $\bar{X}_6$ is dependent only upon the average variance within the strata or upon the within-strata range $\bar{R}$. Since we assumed $\bar{R} = 3.15$ for both strata, the average within-strata standard deviation, σ_w, of the individual measurements within the strata is given by the formula,

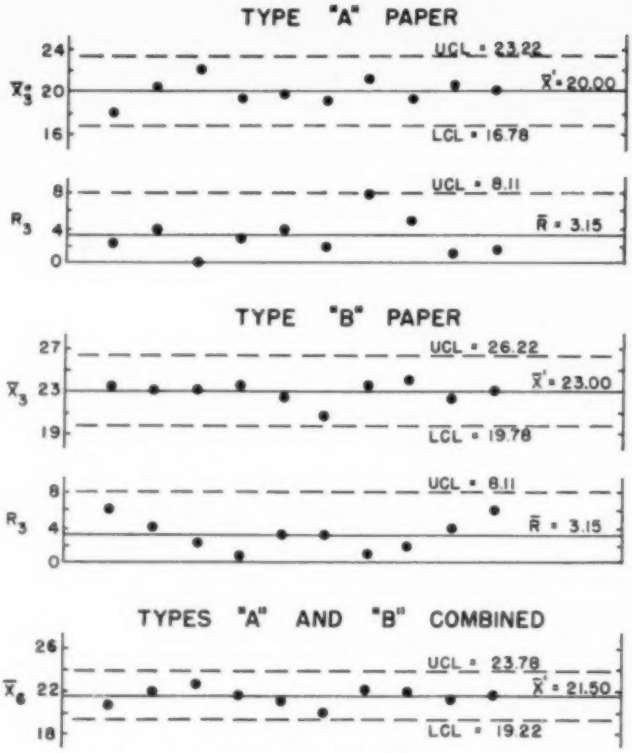

Figure 1—**Control Charts for Tensile Strength of Paper**

$$\sigma_w = \bar{R}/d_2 = 3.15/1.693 = 1.86.$$

It then follows that the standard deviation, $\sigma_{\bar{X}}$, of the average, $\bar{X}_6$, of the six measurements is $\sigma_w/\sqrt{6} = 1.86/\sqrt{6} = 0.759$. Since the standard, $\bar{X}'_6$, is $(20 + 23)/2 = 21.5$, the control chart limits for $\bar{X}_6$ are,

$$\bar{X}'_6 \pm 3\sigma_{\bar{X}} = 21.50 \pm 3(0.759) = 21.50 \pm 2.28,$$

or 19.22 and 23.78. The spread (4.56) of these limits is equal to the spread (6.44) of the previously calculated limits for the averages of three, divided by $\sqrt{2}$.

If the six tensile strength measurements on the two types of paper were to be considered as six independent random measurements from the same cause system, the ranges for the ten samples of six would be as shown in the R_6 column of Table 2. The average, $\bar{R}$, of these ten values is 5.9. Using the standard formula $\bar{X}'_6 \pm A_2\bar{R}$ for samples of size six, the limits for the $\bar{X}_6$ control chart would then be,

$$21.50 \pm (0.483)(5.9) = 21.50 \pm 2.85,$$

or 18.65 and 24.35. These limits are 25% wider than the correct limits, 19.22 and 23.78, calculated above. Thus, if the subgroup is divided into well defined strata and all strata are sampled, then the control chart limits for the average of the measurements within the sample will be too wide if the stratification is disregarded.

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Acceptance Inspection of Purchased Material*

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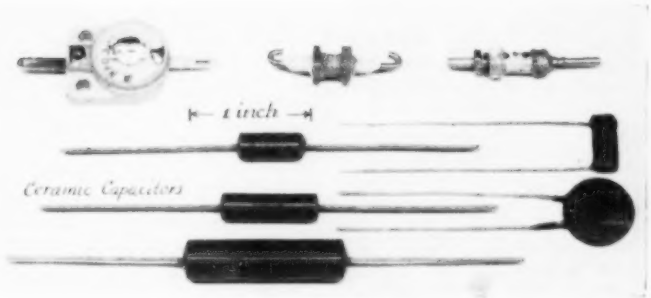
ELECTRICAL COMPONENTS

A rather specialized inspection problem is presented in the purchase of electrical components such as resistors, varistors and capacitors which are used in large numbers to build up networks and amplifiers. While most of these are shipped to Western Electric for manufacturing purposes rather than direct to telephone companies, the procedures followed in inspecting them are felt to be of sufficient interest to warrant their description. The use of these components contemplates operation over a long period of years with no appreciable change in their electrical characteristics. In the usual case, those features which insure the desired service life for such components are presumed to be incorporated in the design, and inspection, where it is made at all for such purposes, is confined to type-testing one of the first units to be supplied. Experience has shown us however, that, with current trends in design which contemplate exacting performance from units which have been greatly reduced in physical size, process variations from time to time may introduce life-performance limitations of serious magnitude. It is desirable, therefore, that some form of inspection procedure be formulated which will not only include the normal lot-by-lot acceptance inspection but will supplement it in such a manner as to afford continuing evidence as to the integrity of the manufacturing process from the standpoint of service life insurance.

In addition, therefore, to the normal mechanical and electrical requirements which may be verified immediately by straightforward testing procedures, accelerated aging requirements are specified in the design specifications to insure satisfactory quality from a life standpoint. Tests for these latter requirements are destructive, expensive, and time consuming. Until they are completed, however, the actual quality of the product is not verified. This means that life tests must be confined to a relatively small sample, and that indications of acceptability of the product must be obtained as early as possible in order to permit shipment of the lot in question.



Ceramic Capacitors

The instruction covering the inspection of ceramic capacitors will serve as a good illustration of the manner in which an inspection problem of this kind is handled. A double sampling lot inspection table with a lot tolerance of 3% and a consumer's risk of 10% is provided to cover the sample to be inspected for dimensions and surface inspection (including such features as finish, end sealing, tightness of terminals, freedom from sharp edges, spacing and location of color code, etc.) A specified portion of the surface inspection sample is subjected to those electrical tests, such as dielectric strength, capacitance, and insulation resistance, which can be made at once. Figure 3 shows an excerpt, Section 4, of the instruction. (This section covers the inspection of the product for features which have significance from the standpoint of service life and which involve subjecting the capacitors to extreme temperatures and accelerated aging.) Par. 1.7 referred to at the heading of the section states that for this particular purpose production is arbitrarily divided into lots of 3500 or 7000 of one type of capacitor.

The text in the figure explains the procedure adequately. Note that inspection is reduced by half provided a suitable quality level is maintained as indicated by consistently meeting the acceptance criteria. Note also that under certain circumstances of nonconformance, information is referred to Headquarters for decision as to the action to be taken. Provision is made in the inspection procedures for the acceptance of nonconforming lots of material when approved by Bell Laboratories. In the instance at hand, however, questions arise not only in respect to conformance of the one lot represented by the sample, but also in respect to product which may already have been shipped, and to product to be made in the future. The testing time element makes such cases a matter for consideration by specialists and adequate instructions cannot be supplied a priori to cover these cases.

One might ask why sample sizes of 6 or 12 have been selected as shown in the table. The answer is that together with the allowable defect numbers shown (0 or 1) these samples represent the minimum number that we can afford from a protection standpoint for the features in question, and the maximum which can be justified on an over-

*This is the concluding part of the paper begun under this title in the September issue.

*4. INSPECTION: PERIODIC (Par. 1.7)

4.1 Table of Sample Sizes and Allowable Defect Numbers.

Inspection Item	Normal Inspection Lot Size	Sample Size-n	Allowable Defect Number-c	Reduced Inspection Lot Size	Sample Size-n	Allowable Defect Numb-
Life	3500	12	1	7000	12	1
Seal	3500	12	1	7000	12	1
Torque	3500	12	1	7000	12	1
Drip	3500	12	0	7000	12	0
Ins.Res. at Ab. Temp.	3500	12	0	7000	12	0
Hi Freq. Imped.	3500	12	0	7000	12	0
Temp. Coeffic.	3500	6	0	7000	6	0
Cap. Drift	3500	6	0	7000	6	0
Vibration	3500	6	0	7000	6	0

#If during any quarter combined production under a single specification is less than 3500, samples for these tests shall be selected as shown under Normal Inspection considering that quarter's production to be the inspection lot.

##When pertinent.

4.11 In so far as practicable the number of pieces selected from each list number shall be in the same proportion as the amount of that list number in the lot, except that pieces selected for Torque Test shall be selected by size and type of threaded part rather than list number.

4.2 Sampling Procedure for Inspection per Paragraphs 4.21 to 4.48, inclusive.

4.21 Normal Inspection - Select representative sample n from lot for test for each inspection item as shown under Table, Paragraph 4.1.

4.211 Place respective samples on Life Test, and Seal (Cycling) test (when pertinent), and make other tests and determinations (See Par. 4.4).

4.212 If defects found in tests other than Life and Seal exceed allowable defect number, report lot as non-conforming.

4.213 At end of Seal and of 100 hours of Life Test check samples as noted in Paragraph 4.4; if no defects are noted for either inspection item, shipment of lot may be permitted pending completion of test (provided lot is not being held for disposition under Par. 4.212).

4.2131 If not more than one defect is found for Life Test hold lot until completion of full 250 hours of test.

4.2132 If more than one defect is found for Seal or for Life Tests at end of 100 hours, continue remainder of sample on test but class lot as non-conforming and forward test results to New York Office immediately.

4.214 If shipment has been authorized at end of 100 hours of test but allowable defect number c has been exceeded at end of test, notify New York Office immediately giving full details.

4.22 Reduced Inspection-When 4 consecutive conforming lots have been found for an inspection item under Normal Inspection, inspection for that item may be made in accordance with the Reduced Inspection Table.

4.221 Sample selection and criteria shall be applied for Reduced Inspection in the same manner as that enumerated under Paragraphs 4.21 to 4.214 inclusive.

4.222 If a lot is found non-conforming under Reduced Inspection, sampling and test shall immediately revert to the Normal Inspection basis.

4.3 Sampling Procedure for Inspection per Paragraph 4.45.

4.31 Select random sample of at least 10 specimens of each ceramic component used during current fiscal quarter from supplier's stock and inspect per Paragraph 4.45.

4.32 If any specimen does not conform, report current product involved as non-conforming.

4.4 Tests and Determinations.

4.41 Capacitors subjected to Torque, Accelerated Life and Seal (Cycling) Tests shall be checked for Dielectric Strength Capacitance, Insulation Resistance (and Q, when pertinent) before test, and Capacitance, Insulation Resistance (and Q, when pertinent) after test; Torque Test samples shall be checked for Dielectric Strength after test; also; the Capacitance, Insulation Resistance (and Q, when pertinent) values obtained before and after test shall be recorded.

*4.42 Temperature Coefficient, Capacitance Drift, Wax Drip, Torque, Insulation Resistance at Abnormal Temperature, High Frequency Impedance (Q), and Vibration (when pertinent) tests.

4.421 Each capacitor in the respective samples (Par. 4.21 or 4.22) shall be tested or inspected.

4.43 Accelerated Life Test.

4.431 Each capacitor in the sample shall be tested. The Capacitance and Insulation Resistance shall be measured and recorded at the end of 100 hours as well as before and after test. Capacitors subjected to this test shall not be shipped.

4.44 Seal Test (Cycling)

4.441 Each capacitor in the sample shall be tested.

4.45 Water Absorption

4.451 The sample (Par. 4.3) shall be tested for water absorption as outlined in Paragraphs 4.4511 to 4.4514, inclusive (which are based on Method A, A.S.T.M. D116).

4.4511 The specimens (Par. 4.31) shall furnish at least five test samples with a weight of 2 grams to 50 grams each when weighed on a chemical balance, and shall have at least 25% of the surface newly fractured (unless otherwise stipulated).

4.4512 The test samples shall be dried at 120°C. for two hours in an oven capable of maintaining a temperature of 120° ± 5°C., cooled in a desiccator to approximately room temperature and each test sample weighed immediately upon removal from the desiccator.

4.4513 The samples shall be totally submerged in briskly boiling distilled water for 30 minutes, removed and quenched in distilled water at room temperature (about 20°C.), the surface water wiped off with a soft cloth and the samples weighed immediately.

4.4514 The percentage water absorption of each test sample and the average percentage water absorption of all samples tested shall be computed from the dry weight and weight after immersion of each sample.

4.46 If a defective capacitor is found in sample when tested as noted in Paragraph 4.41, it shall be replaced by a conforming unit selected from the lot.

4.47 When time is available during the course of the inspection, the inspector shall observe the method of construction.

Figure 3—**Ceramic Capacitors, KS Types—Sampling Plan for Accelerated Life Tests, etc.**

all economic basis, insofar as our present knowledge enables us to determine these factors. It is always preferable, if it can be justified, to arrange for an AN* of at least one, since with an AN of zero any defect means nonconformance. We can do so with the first three items listed in the table. For the remainder, the sample size necessary cannot be justified and we do better to arrange for the special handling of those instances where a failure is encountered.

The technique described in this procedure is one which may be subject to revision as further experience is obtained. We are still to some extent feeling our way as to the best solution. The plan is definitely better, in any event, than reliance on the assumption that the process, which produced the component which proved acceptable in the "type" test, will continue to be satisfactory indefinitely with no surveillance other than by the usual end-test checks.

WIRE PRODUCTS

While most of the products involved in purchases of telephone supply items are best inspected by the method of attributes—all are inspected by this method for quality characteristics which are not quantitatively specified, i.e., "judgment"

*AN = Acceptance Number

items—economies made possible by the method of variables sometimes dictate the use of this method. Consider, for instance, some of the wire products such as insulated electrical conductors, suspension strand, armor wire, and lashing wire. These products are usually submitted for inspection as coils or reels. For such requirements as tensile strength, elongation, adhesion of insulation and the like, tests are destructive and sampling is mandatory. Regardless of whether we consider each coil or reel separately, we are still usually limited to a sample of one or two specimens per unit since to take more would require uncoiling and recoiling and shorten the length in which the material is furnished. Under conditions where the distribution of the characteristic is known to be reasonably close to normal, as it is in many cases, the product can be evaluated quality-wise on the basis of criteria expressed in terms of $\bar{X}$ and the range of reasonably small samples.

In the inspection of drop wire conductor, for example, measurements are made for conductor resistance, breaking strength, and elongation on one specimen from each of 10 randomly selected coils. Maximum or minimum limits, as appropriate, are imposed on the average of the ten results and an attributes criterion, $AN = 0$, on the limiting value for a specimen. Should the product give a first indication of non-conformance under these criteria, a second sample is inspected on an attributes basis in accordance with a double sampling table, the first 10 specimen results being included as part of the first sample under the table. The savings in inspection effort which are possible as compared with an initial attributes plan are appreciable when incoming quality is good.

It might be of interest at this point to cite an instance of what can be done in the way of real savings in inspection effort when we can get right back into the process. The Western Company manufactures very large quantities of drop wire in its own plant. Detailed analyses have been made by Laboratories from time to time concerning the magnitudes and variability of the quality parameters of this product. One of the important requirements is that there be a minimum bond of adhesion between the rubber insulation and the conductor. Proper adhesion insures longer life and helps to prevent slippage in the clamps which are used to suspend the drop wire between the telephone pole and the subscriber's premises. The insulation is extruded onto the conductor and vulcanized all in one continuous process. Operation is generally on a 24 hour per day basis and a number of individual extrusion machines are necessary to supply the required output. The process is excellently controlled with respect to individual machines, to separate daily shifts, and to seasonal and long-time variations.

It was formerly the practice to employ an attributes procedure for the inspection of adhesion in which two specimens from each of about 10% of the manufactured coils of drop wire were measured for this feature—some 18 to 20 thousand specimens per month under out-put figures approximating 165 million conductor feet per month. For quality assurance purposes, Laboratories requested monthly percentage failure results on 1,800 to 2,000 specimens, along with actual measurements of adhesion in pounds on 200 specimens per month. Under the current inspection procedures, developed as a result of the detailed analyses mentioned, the inspector measures normally only three sets of four specimens each per day—a total of about 250 specimens per month—and plots the results on a specially designed control chart. This is all the inspection made for this feature unless the results indicate lack of control, in which event the procedures call for the successive application of three separate sets of criteria, each calling for sizeable increases in inspection over its predecessor. Since each specimen is only a few inches in length, the current procedures call for the examination of less than a millionth of the wire under normal conditions.

Furthermore, all of the necessary inspection information is obtained directly from regular shop inspections, and successive inspections which are normally applied by Western are eliminated entirely. While the savings possible with this plan as compared with the best of attributes inspection procedures are obviously enormous, it should be pointed out that the control type of inspection carried to the degree here indicated is possible only when product is very well controlled and at very satisfactory levels.

AUTOMOTIVE EQUIPMENT

Under the general classification of automotive equipment, the Bell System purchases a large number of items used for outside plant construction purposes, station installation and maintenance, coin box collections, etc. These comprise various types of bodies for mounting on automotive chassis, trailers, tools such as winches, pole derricks and earth boring machines, which are powered by the automotive engines, and accessory equipment. Inspection of this type of product is covered by a series of inspection instructions designed to provide for features peculiar to this specialized line of apparatus. As would be expected from the nature of the product, certain requirements involve a different order of processing accuracy than is the case in many of the other types of product referred to previously.

The component parts of winches, power take-offs, and boring machines, for example, must be made of carefully controlled alloys, machined to close fits, and heat treated to insure strength and durability. Production volume is generally not large enough to warrant the type of assembly line common to the production of passenger automobiles, with the result that production of individual lots is not essentially continuous from the standpoint of inspection treatment. Much of the quality in the finished product, furthermore, is the result of hand operations such as riveting, welding, and finishing. Truck bodies, for instance, are much more of a custom-made article than those products referred to before as hardware items.

Inspection procedures for this class of product may be divided broadly into two categories: a sampling inspection of component parts before assembly for the specified requirements such as material, dimensions, hardness, depth of case and finish; and a 100% detailed inspection of the completed product for assembly features, such as riveting, welding, locating, fitting, etc. including an operation test where pertinent. Needless to say, in these circumstances we find in the inspection procedures a minimum of sampling tables and a large amount of text describing the numerous checks to be made and detailed descriptions as to how to make them. Since many of the features depend upon the inspector's judgment, inspector training is an important part of the inspection planning.

PERFORMANCE PER DOLLAR INDICES

Some of the design specifications include requirements which are more satisfactorily and economically verified in a central testing laboratory. The verification may involve the use of special mechanical or electrical equipment, the skills of a special technician such as an analytical chemist, or the more or less constant attendance of an inspector whose continued presence at the supplying plant cannot be justified. Luminosity and life tests on incandescent lamps, and life tests under specified load conditions on dry batteries, represent features which are better handled in a suitably equipped central laboratory. Western maintains such a well equipped and staffed laboratory for inspections of this nature at its New York Headquarters.

Determination of the performance index for incandescent lamps is an illustration of an inspection procedure which is designed primarily to ascertain quantitatively the quality per dollar of the purchased product. Inspection involves in this case the selection of a representative sample of suitable size, the examination of this sample for visual irregularities, and the application of a life test under specified line voltages, with measurements necessary to ascertain the average performance per dollar of the lamps represented by the sample. Since the labor cost of installing a new lamp, or replacing one which has burned out in service, is by no means an insignificant factor in the cost of illumination, it is necessary to take account of this maintenance cost as well as of the direct cost of the lamp itself and its direct operating cost in lumens per watt. A performance factor, P, is therefore calculated from measurements obtained on the sample and substituted in the relationship:

$$P = \frac{(L)(H)}{c + r + (0.001)\,pwH}$$

where

- P = Performance in lumen hours per dollar
- L = Ave. lumens output at 70% rated life
- w = Ave. watts input at 70% rated life
- c = Contract cost of lamp in dollars
- H = Ave. life of lamp to burnout in hours
- p = Power cost in dollars per KW hr.
- r = Replacement or installation cost in dollars

A performance index is calculated for the inspected product by comparing the calculated P with the performance P_s of a standard lamp:

$$\text{Performance Index, } I = 100P/P_s$$

INSPECTION FOR DESIGN INFORMATION

Inspection results frequently supply important information which serves as a basis for revising current, or establishing new, design specification requirements. Regular studies of inspection results are made by Bell Laboratories, of course, to insure that the specification requirements are such as to permit the continuous economical supply of materials. In some circumstances, information needed for development purposes is not furnished in the most useful form by the current inspection procedures. This is especially true in those cases where the instructions, designed as they have been to provide the most economical inspection methods, may call for results on an attributes rather than a variables basis. In such cases it is common practice to supplement the instructions by additional instructions or special addenda which remain in effect long enough to secure the necessary development information.

For example, the instructions covering normal procedures for the inspection of clay conduit call for attributes inspection on many of the dimensions controlling the satisfactory lineup of successive lengths of the conduit. The conduit is an extruded fired ceramic material used for underground cable installation and is furnished in 1, 2, 3, 4, 6, 8 and 9 duct forms. It is purchased from many sources advantageously located geographically from a freight standpoint. Because the manufacturing process has not been very well controlled, it has been necessary to permit fairly wide dimensional tolerances for the finished product. The dimensional variations cause difficulty in laying the material satisfactorily, and this is aggravated when product of two suppliers is intermixed as supply conditions may demand. Our development engineers estimated a considerable saving in installation costs to the Operating Companies if, by more exacting dimensional requirements, the interchangeability of the material dimensionally could be improved.

A special inspection instruction was prepared and data were secured by the inspectors and analyzed by the Laboratories. This analysis showed that a large part of the dimensional variation resulted from lack of control of the extruding die dimensions within a plant and from plant to plant. An approach to the suppliers, explaining the objective and discussing with them the shortcomings and desirable changes in their manufacturing processes by the introduction of simple control procedures, has enlisted their cooperation to the point where improved (more restricted) dimensional requirements have already been made possible, and further improvements are likely.

AUXILIARY INSPECTION INFORMATION

Supplementary to each of the detailed procedures covered by the various inspection instructions are certain general procedures which are necessary to facilitate the inspections, to provide for the necessary inspection results information, and to insure the continuing accuracy of the results obtained. These are incorporated in the individual instructions or in general instructions which form a part of the complete inspection procedures applying to any given product. Their specific nature and purpose are as follows:

1. Evidence which can be associated with the product as to its acceptance on the basis of Western's inspection is usually desirable. The instructions specify the type of inspection evidence required, whether it be by tagging, stamping, sealing, etc., and where the evidence is to be placed—on the item itself or on the container.
2. Specification requirements which call for the use of certain materials, such as brand of paint, or the application of a certain sequence in processing, such as "form before annealing," or the completion of processing after inspection, such as painting, and the like, are frequently accepted on the basis of certification by the supplier.
3. Each instruction delineates the type, quantity and form of the inspection results information to be reported by the inspector.

4. Each instruction has a general statement to the effect that the supplier will furnish facilities necessary for the inspections, and specifies special requirements in this respect when pertinent.
5. Separate instructions are provided to cover the method and frequency to be employed in checking the accuracy and maintenance of testing equipment, gauges, meters, standards, testing machines, etc.
6. Separate instructions are provided to help the inspector perform his inspections in the most expeditious fashion. Notable are those instructions which furnish tables or charts for converting an inspection result into terms directly associated with a specification requirement.

CONCLUSION

The foregoing illustrations of acceptance inspection procedures represent obviously a small fraction of those necessary to provide properly for the large variety of Bell System purchases. It is hoped, however, that even such brief description and comments as have been given will help to point out some of the many considerations necessary to the formulation of the best methods under a given set of circumstances. Where relatively little manufacturing information is available, as may be the case with new products, the inspection procedures must be formulated on the basis of whatever pertinent information the inspector can obtain before actual inspection experience with the product. The procedures are then set up with assured protection as the main goal. Modifications with an eye to economy may thereafter be introduced as the results of the initial inspections may serve to make these possible.

It is apparent that each procedure should be tailor-made, with the close inter-relationship between design, manufacture, inspection methods, use of the product, and commercial considerations ever in mind. These factors are constantly changing, with the result that the best inspection procedures can never be assumed to be completely stabilized. Especially in these times of material shortages and mandatory substitutions it is important to be on the alert to make sure that the procedures are modified as circumstances warrant. When inspection economies have been introduced as a result of knowledge of the underlying processes and materials, it is doubly advisable to anticipate any effects of changes in these processes and materials and to revise the inspection methods as necessary. It is apparent also that the inspection personnel must be well trained. So many of the specification requirements must be evaluated by judgment that an important element in the cost of the material as well as in its quality rests, in the last analysis, upon the judgment of the individual inspector. That the inspection procedures and the personnel who use them have, in general, been well chosen is attested by the hearty endorsement of the whole arrangement by the many suppliers whom they affect.

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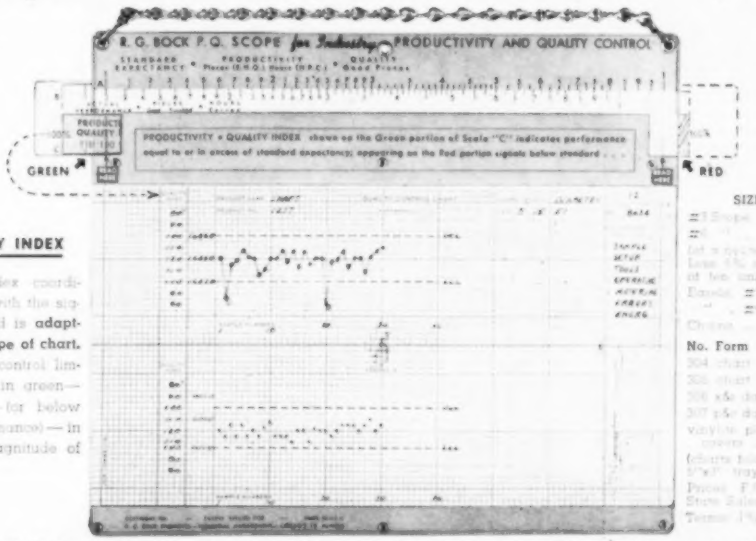
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A Brief Survey of the Practicability of MIL-STD-105A within the Aircraft and Associated Industries

FAY CARLSON
Sundstrand Machine Tool Co.

AT THE first national meeting of the Aircraft Technical Committee held in Cleveland May 25, 1951, one of the paramount items of discussion was the applicability of MIL-STD-105A within the aircraft and associated industries. It was decided that a survey be made of the companies represented on the committee to determine whether such a standard was desirable, to what extent it was being used or its use anticipated, and whether in its present form it provided a practical tool. Two questionnaires were circulated to eighteen companies. Twelve responded to the first and eight to the second. Granted this was not a very large sample, but it was by the nature of the respondents none-the-less significant. Included in this group were airframe manufacturers, engine manufacturers, and accessories manufacturers. The fact that six companies did not respond might be construed as a rather negative attitude toward the subject on their part.

Questions and responses to Questionnaire I were as follows:

Paragraph 1.1 of MIL-STD-105A reads:

"When applicable and desirable the Standard shall be referenced in the specification or contract, and provisions set forth herein shall be followed."

Q. Are you using MIL-STD-105A in the inspection of your government contract work?
A. Yes—4
Limited application—3
No, but planning to—3
No, and not planning to—2

Q. Is it a requirement of your contract?
A. Yes—3
No—7

Q. Do you find that extensive deviations from the application outlined in the Standard are necessary in order to adapt it to your use? If so, has the government approved such deviations?
A. Yes, with government approval—1
Yes, without government approval requested—1
No—7

From the foregoing, it is pertinent that all but two companies are either undertaking or expect to undertake the application of the Standard. However, more than half of them did not find it a requirement of their contract.

Paragraph 1.5 of MIL-STD-105A reads as follows:

"Sampling plans specified in this Standard are applicable to the inspection of the end product, product in process of manufacture, or components thereof."

Q. Are you making application of MIL-STD-105A to process control through line or patrol inspection?
A. Yes—4
No—3

Q. If so, do such charts or records constitute adequate evidence for acceptance purposes on the part of the Military?
A. Yes—3
No—1

Q. Do you use it for bench inspection and final inspection of component parts?
A. Yes—6
Purchase parts only—1

Q. Do you use it for inspection and acceptance of sub-assemblies?
A. Yes—2
No—4
Limited application—1

Q. Do you use it for inspection and acceptance of final assemblies?
A. Yes—1
Plan to—1
No—5

Of the seven companies that have made a start, emphasis seems to fall first on bench inspection of manufactured and purchased component parts. To a lesser degree application is being made to inspection of sub-assemblies and line inspection. Only one company is accepting the finished product on the basis of sampling. It is noteworthy, however, that in three companies, line charts and records built around these tables constitute basis for acceptance of material.

As hopeful as this information appears, the fact that the barest beginning has been made in most instances is clearly indicated by this question:

Q. Have you effected a classification of defects?
A. Yes—2
Limited classification—2
Plan to—1
No—3

Resistance to the idea of classification was the major objection raised in the commentaries that accompanied many of the questionnaires. Many felt that such an effort would be time-consuming to an extent that would largely outweigh any advantage gained.

Never-the-less the favorable response regarding the desirability of standardization of sampling methods is certainly reflected in this question:

Q. When the current national emergency ends, would you welcome a continuation of such standardization on an industry wide basis?
A. Yes—8
No—0

Undecided or no comment—3

Furthermore, confidence in the sampling plans is expressed in response to this question:

Q. Are you using these sampling plans on any of your commercial products?
A. Yes—5
Receiving Inspection only—1
Plan to—1
No—2

In Questionnaire II the following were asked:

Q. Are you using or do you anticipate the use of the type of evaluation described in paragraph 3.3 (defects per hundred units)?
A. Yes—0
No—6
Plan to—2

Paragraph 4.2 states that the particular AQL values to be used for a given product shall be specified by the government.

Q. Has the government specified Standard AQL's applicable to each of the respective classifications of defects?
A. Yes—3
No—5

The three companies that answered "yes" to the preceding question stated the Standard AQL's as follows:

#1
AQL's
varied

#2
Critical—100% inspection
Major—1.5% AQL
Minor—4.0% AQL

#No. 3
Critical—0% AQL
Major—1% AQL
Minor A—2.5% AQL
Minor B—6.5% AQL

Q. Do you find it practical in all cases to perform to the requirement set forth in paragraph 5.1.1, formation of lots?

A. Yes—2
No—4

Q. The computation of process average set forth in paragraph 8.1 requires that ten consecutive lots be the basis for the estimate. Do you follow this practice and find it practical to do so?

A. Yes—0
No—3
When practical—2

Paragraph 9.1 states that the government shall determine whether normal, tightened, or reduced inspection will be used with respect to the products submitted by a particular supplier.

Q. At present under which of these headings is the bulk of your inspection carried out?

A. No level established—1
Normal—5
100% inspection—1

Q. At the start of the contract which one of these levels was specified?

A. Normal—4
100% inspection—1

Q. Under section 9 do you generally agree with the mechanics as stated for tightening and reducing inspection?

A. Yes—6
No comment—1
No—1

Q. Do you consider MIL-STD-105A adequate as an inspection criteria for your product?

A. Yes—4
Receiving Inspection only—2
No—1

On the strength of the response to both questionnaires one might conclude that many of the aircraft contractors are willing to apply or discuss the possible application of MIL-STD-105A in their plants. In spite of some misgivings about certain aspects of the standard, there is a general agreement on the subject of further standardization on an industry-wide basis.

Certain installations have quite obviously integrated MIL-STD-105A effectively into their inspection practice and a high degree of coordination between government and plant inspection exists. However, there may be some validity to the opinion that in too many cases the government representatives at the local level have not taken the initiative regarding designation of inspection levels, AQL's, and tightening and reducing inspection. There is no clear evidence that government inspection has arrived at a mutual and workable agreement with management regarding the application of MIL-STD-105A in the cross section of companies covered in this brief survey.

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Directions for ASQC

J. M. JURAN
Consulting Management Engineer

THERE are three main directions in which the American Society for Quality Control is being urged. These directions can best be visualized by reference to Chart A.

Chart A shows (in simplified form) the relationship of the functions of an enterprise to the management tools for carrying out those functions. The functions head up the vertical columns. The management tools are listed horizontally. Any intersection represents the use of a particular management tool to carry out a particular management job.

The three main directions being urged on ASQC are as follows:

(1) As a promoter for use of statistical methods in all functions of the enterprise. This is represented on Chart A by the wide horizontal band embracing all statistical methods, and cutting across all functions of the enterprise. The emphasis here is on *statistical methods*.

(2) As a promoter for use of tools of scientific management in all phases of the quality function. This is represented on Chart A by the various vertical bands. Each of these bands represents a function which is immediately or closely related to the quality function. Each vertical band cuts across all management tools used to accomplish that function. The emphasis here is on the *quality function*.

(3) As a promoter for the use of statistical methods in the quality function. This is represented on Chart A by the intersections of the wide horizontal band with those vertical bands related to the quality function. Here the emphasis is on *statistical methods in the quality function*.

The foregoing three possible directions are not a complete list of possible directions for ASQC. There are members who have prime interest in general-use mechanical tools (instruments, machine tools, etc.). Other members have prime interest in some one process (grinding, plating). Still others have prime interest in some one product (gas turbines, electron tubes), and so on. But the foregoing three possible directions are clearly the most important possibilities for broad direction for ASQC.

In discussing which of these main directions ASQC might best take, it should be clear that each one of these directions has value. None of them is "wrong". In choosing any of them, ASQC will be doing a useful job, though possibly not the most useful job for its membership.

IMPLICATIONS OF A SOCIETY FOR STATISTICAL METHODS IN INDUSTRY

The need for promoting use of statistical methods in industry is clear. The philosophy of scientific management includes the credo—fact, not rule of thumb. Management effectiveness is so greatly improved when founded on facts that the point no longer admits of debate.

To my knowledge there is no professional society devoted exclusively to this field. American Statistical Association has indeed devoted effort to industrial applications of statistical methods, but this has to date been a minor appendage of that Society.

IMPLICATIONS OF A SOCIETY FOR THE QUALITY FUNCTION

The need for promoting scientific management in the quality function is also clear. This function is rising in importance due to the ever increasing production of precision goods. This growing problem simply cannot be solved by the old methods.

There exists, to my knowledge, no professional society devoted exclusively to this function, unless it be ASQC itself. The various management societies, both general and special, have thus far devoted little attention to the quality function. The need for a new professional society is clearly there.

IMPLICATIONS OF A SOCIETY FOR APPLICATION OF STATISTICAL METHODS TO THE QUALITY FUNCTION

Here again there exists at present no professional society unless it be ASQC itself. The comparatively narrow scope of such a society simplifies the expression of unity of purpose. But the narrowness also restricts the potential membership.

It should be noted that any group devoted to this narrow scope can readily be a specialized division *either* of a society for statistical methods in industry *or* of a society for the quality function. It follows that the real choice which has been faced by ASQC is whether (in terms of Chart A) to go horizontal (for statistical methods) or vertical (for the quality function).

THE INTERESTS OF SOCIETY vs. INTERESTS OF ASQC MEMBERSHIP

In the foregoing it has been pointed out that each one of these three directions has value. No one of them is "wrong" from the standpoint of usefulness to the Society. But one of them may well be "right" from the standpoint of the membership makeup of ASQC. The rightness can, to a large degree, be judged by an analysis of that membership makeup. Happily, the latest membership roster includes job titles for about 80% of the membership. These job titles* are the basis of the analysis which follows.

* A study of titles prevalent in the field is an adventure in semantics. In the Boston Society for Quality Control, a member can eke out a livelihood as Quality Control Engineer, Quality Control Technician, Quality Checker, Quality Control Coordinator, Quality Control Auditor, Quality Control Staff Engineer, Quality Control Chemist, Statistical Engineer, Control Analyst, or Quality Engineer. His supervisor carries titles such as Quality Control Supervisor, Quality Control Director, Quality Control Manager or Director of Quality Control. He would have much to do with men who have the rank of Inspection Foreman, Chief Inspector or Inspection Manager. If these are not enough, it is still possible to find others called Quality Supervisor, Quality Superintendent or Quality Manager.

All titles in the foregoing list are to be found among the membership of a chapter having at the time (Feb. 1, 1951) a total of 120 members.

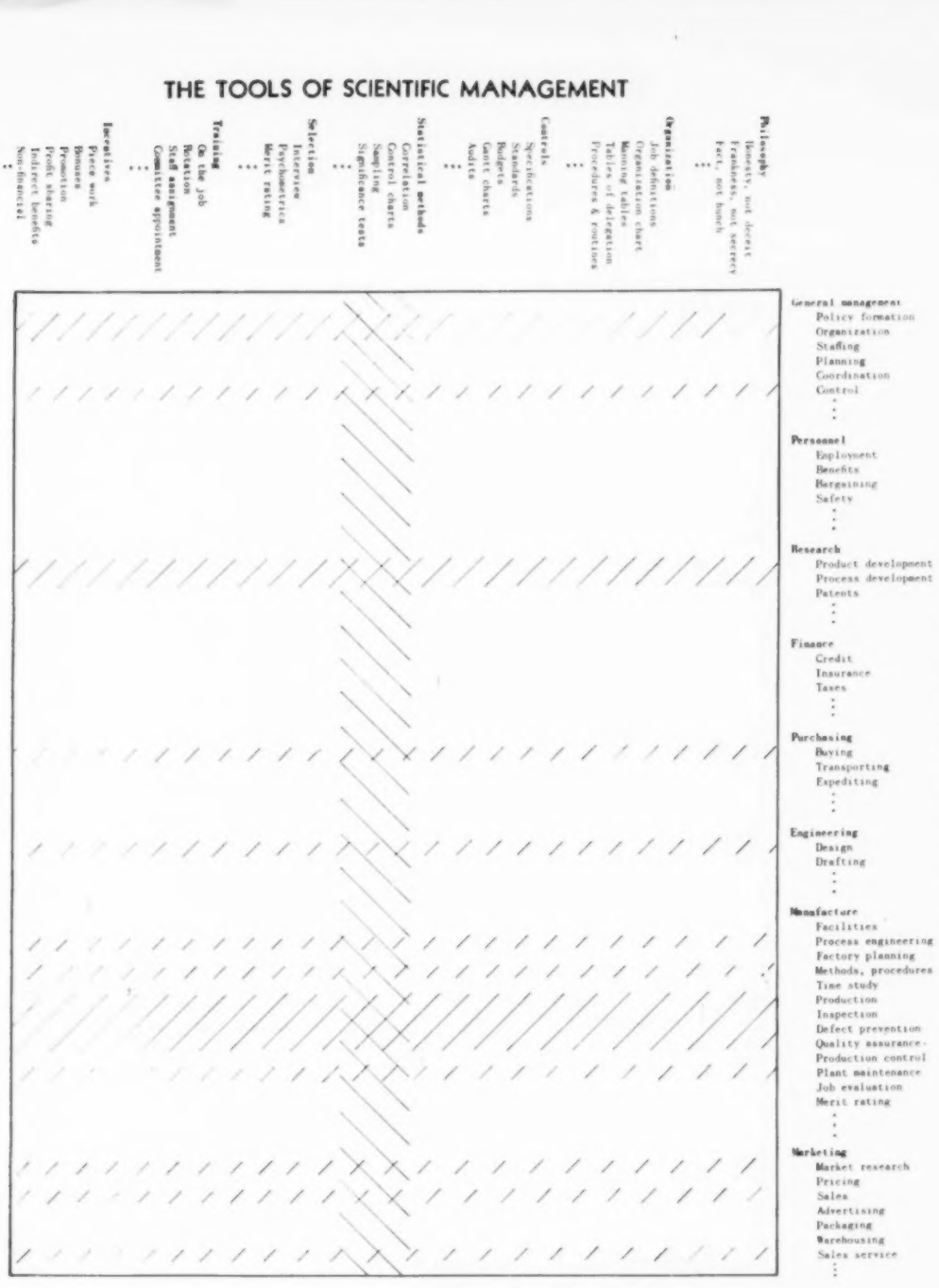

CHART A—**Relationship between Functions of an Enterprise and Tools of Scientific Management**

Editorial Note: Turn this chart 90° to the left for the interpretation given by the author.

ANALYSIS OF MAKEUP OF ASQC MEMBERSHIP

Of the 3708 members of ASQC as of February 1, 1951, 2953, or 80%, gave their titles to an extent which can be classified reasonably. The major classifications appear in Table 1.

Conclusions which may be drawn from these data include the following:

(1) About a third of the membership is primarily concerned with quality problems in inspection and production, i.e., (c) and (d).

(2) Well over a third of the membership is primarily concerned with applications of quality control to industrial processes, i.e., (a), (b) and part of (e) and (f).

(3) A substantial segment of membership, i.e., (e) and (f) consists of engineers and scientists whose prime interest in the quality function is neither in inspection nor in "quality control".

Manifestly, there is some room for interpretation as to the significance of Table 1. But there is no mistaking the main lesson. ASQC today is *not* a society for statistical methods in industry. Nor is ASQC today a society for statistical methods in the quality function. ASQC today *is*, most emphatically, a society for the quality function.

The membership distribution suggests these conclusions with a finality which may come as a surprise to some, as it has to me. We have been discussing directions for ASQC so much that we have not taken the time to see what direction ASQC has in fact taken. But this distribution of membership admits of no misunderstanding.

Whether ASQC should have gone in another direction is an interesting speculation. It is also a postmortem speculation. The facts are there and they are unmistakable in their implications. If the membership makeup means what the numbers of Table 1 mean, then certain important implications arise with respect to all activities of ASQC; organization, publications, research and all the rest. These will now be considered.

TABLE 1

(a) 402 or about 14% are classed as Quality Control Engineers[1]

(b) 467 or about 16% are classed as Chief of Quality Control[2]

(c) 637 or about 22% are associated with Inspection[3]

(d) 385 or about 13% are other supervisors or executives[4]

(e) 447 or about 15% are engineers or scientists of a description other than quality control (industrial engineers, physicists, etc.)

(f) 215 or about 7% supervise a technical function other than quality control (chief chemist, etc.)

(g) 136 or about 5% are classed as statisticians

(h) 138 or about 5% are professors or instructors[5]

(i) 126 or about 4% are miscellaneous, including students, consultants, accountants, etc.

1. Quality Control Engineers is a generic term for all job titles which indicated a technical, non-supervisory responsibility in quality control.
2. Chief of Quality Control is used here to designate those job titles which are related to quality control and are supervisory in character. Some of these titles include supervision of other functions such as inspection, standards, etc.
3. These are usually chief inspectors, inspection foremen and inspectors for the Armed Services.
4. These include plant managers, production superintendents, vice-presidents, etc.
5. Usually either in mathematics or in engineering.

ORGANIZATION FOR ASQC

The chapter as a unit of organization is fundamental in ASQC as in most professional organizations. It is the geographic unit, permitting industrial neighbors to convene for the common good. Clearly, this is an essential dimension of organization.*

A second dimension of organization is by product. ASQC has already generated committees as to various products. These product committees can perform a useful service with respect to the quality problems surrounding such products.

A third dimension of organization is by process. If process committees or divisions were established, there might be a foundry committee, a screw-machine committee, a metal plating committee, etc. Such committees have great potential value because of the fundamental character of the "process" as a center for quality control activity.

For example, a crying need in industry is the calibration of all vital processes in terms of *process capability*. The concept of process capability, and the usefulness of the resultant measures, are truly striking. I have seen many, many chronic problems in defect prevention solved elegantly through measure of process capability. ASQC could make a most valuable contribution to industrial harmony by setting up a Committee on Process Capability. The function of this Committee would be to establish criteria for measuring capability of any industrial process. Thereby, the way would be opened for measurement and publication of the capability of all industrial processes, metal cutting, rolling, calendering, plating, molding, etc.

* The "regional" structure superimposed on the chapter structure is less usual in professional society organization but is certainly not unusual. I have no suggestions as to this.

A fourth dimension of organization is by function. For ASQC members, these functions would include Statistical Methods, Vendor Relations, Product Design, Process Engineering, Measurement, Insspection, Organization for Quality, Assurance of Quality, Economics of Quality, Customer Relations on Quality, Quality Incentives, and still others. Committees for functions such as these are particularly valuable for conduct of research of a character which can benefit all members, no matter what product or process is their special interest.

As such committees on products, on processes and on functions are formed, their work comes to fruition in meetings, researches and publications. The resultant papers and research reports would be a welcome addition to industrial progress. They would also be a welcome addition to the present ra her sporadic sources of society publications.

RESEARCH IN THE QUALITY FUNCTION

Compared to other professional societies of equal size, ASQC is under-organized for research. Yet the opportunity for research in the quality function is boundless. The extent of the potentialities can be realized when we consider the extensive work already done in statistical methods. Here is the one phase, of many in the quality function, which is relatively well developed. But when it comes to the quality aspects of Vendor Relations, Product Design, Process Engineering or Customer Relations, we are in a primitive state

of development. We are equally primitive in our development of Economics of Quality, Organization for Quality, Assurance of Quality, Incentives for Quality and other important fields.

Research in all of these fields is very likely going on among individual members of ASQC. But the effectiveness of these researches can be multiplied greatly through setting up of research committees composed of interested, qualified members.

Obviously, if numerous research committees are set up, some will be productive and some will not. This dispersion is inevitable. All professional societies are faced with this and with the associated necessity for periodical clean-up of dead wood on committees.

With respect to research, experience in professional societies has shown that research is best conducted by the "grass roots" committees and not through any central research committee. However, a central Research Committee is of value in discovering what research is being or should be conducted, in publishing the agenda of researches and research problems, and in stimulating conduct of research.

PUBLICATIONS

A "gripe session" at professional societies is never complete until a few swings have been taken at "publications". As a former chairman of the Publications Committee of a large engineering society, I can speak with some authority here.

There is a vague belief among professional society members that the publications committees can somehow generate more and better papers. In like manner, there is a general belief among publications committee members that somehow the membership can generate more and better papers. Neither of these beliefs is well founded.

The best sources of papers for publications are the group activities of the Society. Papers prepared for delivery at meetings and papers prepared under research committee auspices are today the most fruitful sources of professional society publication.

ASQC is very young, certainly too young to have organized many effective committee and research teams. But at the same time ASQC should proceed forthwith to extend greatly the committee and research struc-

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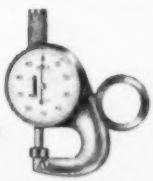

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ture. It is not only the means of securing good publications for the long pull; it is a means of broadening greatly the participation of the membership in vital society affairs.

CONCLUSIONS

To my mind, two principal facts emerge in considering directions for ASQC.

The first fact is that ASQC membership reflects a prime interest in the entire quality function, not a prime interest in only part of the quality function, and not a prime interest in statistical methods. The implications of this membership interest are that the organization, the committee structure, the research undertakings, the professional development and the publications must be likewise oriented to the entire quality function rather than to something else. Only in this way will the prime interests of the membership be served.

The second fact is that ASQC organization, while reflecting the geographic and the "type of product" dimensions, does not reflect the dimensions of "type of process" and of function. Committee organization for industrial processes and for the various sub-divisions of the quality function should be greatly expanded.

Editorial Note: This is the paper promised in the "Operation 'Blueprint'" editorial in the July issue. It has much in common with the paper "Installing a Quality Control System", presented by Dr. Juran at the Cleveland Convention of ASQC. Here, however, the author concentrates on presenting his views regarding the objectives that he believes to be particularly pertinent for ASQC in its role as the Society dedicated to the "science of quality control".

Some Reader Responses to Operation "Blueprint"

Quality Control through Probability Statistics

A. C. ROSANDER

Bureau of Internal Revenue, Washington, D.C.

The editor has invited comments on the meaning and scope of quality control, and what type of program is implied therein. This question is important not only to those directly responsible for improving the quality of product and performance, but to those specialists whose professional interests are involved. The writer should like to discuss certain aspects of the problem from the viewpoint of the applied probability statistician.

There are many different ways of trying to control the quality of a manufactured product. We may use methods and controls based upon the principles of physical science. These principles are used primarily to build quality into the product in the first instance. They are used also as the basis of testing methods and equipment, apparatus which may involve a considerable investment if used as the basis of a 100 percent sampling inspection plan. A second method is that of using a wide variety of production and inspection data collected currently. An illustration of this method in which punch card tabulation is used, was described in Systems for April 1951. A third method is to use the principles of probability statistics as illustrated by statistical quality control charts, sampling inspection, and the design of experiments. These three methods are not mutually exclusive—probability statistics can be applied to eliminate 100 percent inspection in the first case and 100 percent tabulation in the second. It may save management from making an excessive investment in testing equipment on the one hand, and in tabulating equipment on the other.

Applied probability statistics builds quality, not only into products and performance, but into data and decisions. Indeed, it is because of the latter that we are able to do the former. By quality data we mean data which are relevant to the solution of a problem. We mean data which are relatively free from bias, data for which random variation is controlled, data of a specified nature, data in the appropriate quantities, and data collected according to certain logical specifications. Applied probability statistics (including supporting techniques) provides a way of doing this. Very often this leads to an effective solution of the problem at a minimum cost. In this connection we cannot emphasize too often that mere quantity of data is no guarantee of its quality, as many opinion polls, sample surveys, censuses, 100 percent tabulations, and 100 percent inspections have shown. There is no necessary correlation between the amount of data in the files and its effectiveness to solve problems. What really counts is the quality of the data. One may do a better job with a small amount of high quality data than with a large amount of low quality data. Applied probability statistics, including statistical quality control, is full of illustrations of the soundness of this principle.

The building of quality into top-level decisions is illustrated by what is called "operations research" or "operations analysis." This movement started during World War II both here and in England for the purpose of solving certain operating problems of military commanders. To do this a team of scientists was selected representing a wide variety of subject matter including physical science, biological science, mathematics, and probability statistics. This team worked with top-level commanders as advisors and consultants. There is no reason, however, why this approach should be limited to the military. Operations research, like quality control, leans heavily on probability statistics and related techniques. Like quality control, it does not encompass the entire field of application of probability statistics to the problems of management. Add the two together, however, and we are getting close to it.

Quality control concentrates on improving the quality of products and performance; operations analysis concentrates on improving the decisions of top-level management.

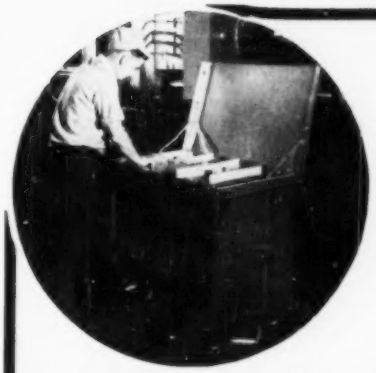
Laymen, specialists, and administrators are forever sampling, estimating, and inferring, often without being conscious of it. Probability statistics helps them do better what they are going to do anyway. The acceptance of the science of probability statistics means that we agree to remove these three areas of our thinking and operating (sampling, estimating, and inferring) from the realm of hunch, intuition, and rule-of-thumb, and make them subject, so far as such application is valid, to this science. This is the challenge with which we are faced. While the implications are far reaching, substantial progress has been made during the past two decades, so that the outlook for the future is promising.

There are those who deny probability statistics, who insist that it is too complicated, that it is mumbo jumbo, that it cannot solve problems, that it is no substitute for common sense or technical judgment, that it will not displace any knowledge one has. These allegations are made despite the fact that probability statistics is the basis of statistical quality control, that quality controllers themselves are using probability statistics more and more, that applied probability statistics has displaced many so-called "commonsense" procedures, that the implications of probability statistics are revolutionary.

The solution lies, not in denying probability statistics, but in accepting it. The solution lies not in trying to thrust an "iron curtain" through probability statistics and saying that we will use what is on one side, but close our eyes to what is on the other. Probability statistics is a unified theoretical science and should be applied as such. The subject matter both theoretical and applied is extensive and is growing rapidly year by year. This growth in itself is evidence of the vitality and power of probability statistics.

The unified application of probability statistics by a professional specialist has many merits. It is the most economical for management. It centers responsibility. It insures an even application of probability statistics throughout the organization. It insures that probability statistics is considered at the planning, as well as at the operating, level. It insures the application of new technical developments. It follows the principle of specialization of function. It centers any in-service training and education relative to probability statistics and its applications.

It is quickly asserted, however, that the probability statistician is too technical, that he does not know how to apply his knowledge, that he does not talk the language of the administrator, that he cannot sell his ideas to planning and operating officials. These criticisms are not new. They have been leveled from time to time at most every type of applied scientist. There is no doubt, however, that some of these criticisms are justified. This is because the term "statistician" has become associated with clerical work involving simple arithmetic operatins which have little to



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do with probability theory and its applications. On the other hand, there are those who have a mastery of the theory of probability statistics but who are unable to apply it to practical problems. Clearly, management interested in applying probability statistics does not want either type.

What management needs in order to get the most benefit from probability statistics is the specialist who is technically trained in the theory and practice of probability statistics, who knows how to apply these principles to practical problems, who keeps up with the developments in probability statistics, who knows how to work with other specialists, who knows how to work with management. If management insists upon specialists of this type, it is going to get them. If it does not, it will have to continue the highly inefficient practice of trying to make a "quickie statistician" out of at least one specialist, irrespective of whether he is a psychologist, salesman, accountant, or lawyer, in every area where probability statistics can be applied.

It is generally agreed that it is a good things for every adult to know something about first aid. That this is sound practice is attested by the many lives which have been saved. At the same time, we recognize that this knowledge of first aid, however important and effective, is no substitute for knowledge of medical science on the one hand, nor for the skill of a professionally trained physician on the other. So it is with probability statistics. Every adult, every specialist, every administrator, should know something about this science because of its universal applications. But this limited knowledge should not be confused with a mature knowledge of the science itself, nor should the application of this restricted knowledge, however effective, close our minds to the need for professionally trained specialists in this field.

The implications of the foregoing point of view for quality control in particular and for management in general are far reaching. The basic idea is that probability statistics is a unified and substantial theoretical and applied science. Once we accept this idea, specialization and professionalization are natural consequences. The task of applying probability statistics to the problems of management becomes a full-time professional job. Comprehensive application takes the place of isolated and piece-meal application. Probability statistics is applied not only to improve the performance of the workman at his machine but to improve the performance of the executive at his desk. Probability statistics can be an effective mode of operation for management. Operations research has pointed the way. If management follows, it will get the maximum return with the minimum investment.

What does all this mean for ASQC? It seems to mean that if ASQC is going to go all out for quality control it will have to give much more attention to the principles of probability statistics and their applications. Above all it should recognize that there are different levels of technical understanding and competence in the application of any science to industry, and probability statistics is no exception. These levels should include policy-making, planning, supervision, and the worker level itself. Each of these levels requires certain knowledges, abilities, skills, and attitudes relative to probability statistics and its applications. A recognition of this differentiation of function will go a long ways toward improving the present situation, including training in probability statistics for quality control purposes.

It means that the concept of quality control should be broadened to include not only the quality of the performance of the factory worker and the office clerk, but the quality of the performance of the administrator himself. To quality of products is added quality of decisions.

It means that ASQC should continue to appeal to the management people at the operating and policy making levels. Management has a big stake in the effective application of probability statistics to its problems, and ASQC is in a position to make a real contribution in this direction.

It means that ASQC might find it desirable to relate quality control and probability statistics to various other fields which apparently have the same broad administrative objectives—work simplification, work measurement, procedural analysis, methods engineering, operations analysis, and scientific management —with the end in view of helping management develop a more effective mode of operation. This interaction and unification appears to be necessary if management is going to keep pace with the new methods revolution which appears to be under way.

THE SCIENCE OF QUALITY CONTROL

Frank G. Norris
Wheeling Steel Corporation

The science of quality control may be considered as a rather broad field bounded by each of the three concepts in the title.

Science

Science implies a distinction from temperamental, empirical, or rule of thumb methods of controlling quality on the one side; and from both the fine and the applied arts on the other side. There is room for and need of judgment in the art of management which means room for personal differences. The results of a scientific procedure can be confirmed, and are free from the effect of personal differences.

Quality

A quality characteristic is any feature of a product or process that can be measured or counted. If both actual and needed performance can be measured, quality may be thought of as the ratio of actual divided by needed performance. In this sense it can be evaluated as a pure dimensionless number. If either intrinsic or functional value can be measured, quality may be regarded as the product of price times value. In this sense quality has the dimension of dollars squared. Both of these concepts however are specialized and perhaps contradictory. The field of quality is of course being expanded as new methods of evaluating vague requirements are developed.

Control

Control requires action for the purpose of change (or equally important refraining from action when none is indicated.) This term limits the field by excluding studies made purely to discover new information; as research, historical descriptions, or studies made for the purpose of prediction as distinguished from control.

This discussion intentionally omits mention of specific procedures as: Statistical methods or statistics, probability or probability controls, and of quality determination which is frequently a first step in quality control.

In certain applications, there is a nice distinction between natural and manufactured products, which a general definition can scarcely hope to resolve. The present tendency is towards an inclusive interpretation.

EXTRACTS FROM LETTERS SUBMITTED

1. FRANCIS B. FISHER

Quality Control Engineer
Century Electric Company
St. Louis, Missouri

The question posed by "Operation 'Blueprint' " is timely.

What are the existing "forms" of SQC today? As in any science, research and cataloging are necessary.

Why not try to find out how various plants in the United States are practicing SQC? Note the conditions peculiar to each plant; take each plant's definition by its *activities* and accomplishments.

Most of what has been presented to date is a series of techniques in mathematics for use in industry. Necessarily, there are many dissimilar applications of the same techniques, around which have grown quality control organizations. In many instances, quality control, in addition to the statistical aspects of its functions, has achieved pretty much the status of a methods department of inspection.

If the proposal made above threatens to require a long time to define the "science of quality control", remember that it may be better to find out what it *is* rather than be content with an abstract definition of what it *should* be.

The writer feels that SQC is not a science, but an empirical approach, using mathematics, to vague standards in Industrialization.

2. GEORGE W. McDERMOTT

Delco-Remy Division, GMC
Anderson, Indiana

Just what is the "science of quality control"?

The question is a challenge to the people who are actively engaged in using and selling quality control.

The science of quality control can be sold at management and shop levels by defining this science as a tool, or a technique, which can be used to evaluate the variations in human behavior, machines, and materials. From this evaluation of variations we get capabilities, comparisons, trends, and predictions which may be made to help control the quality level of any activity.

I am convinced that ASQC is committed to a policy of spreading the knowledge of the science of quality control and to serving as a clearing house for the dissemination of ideas and new developments; it must also serve as a source of standardization of nomenclature, symbols, etc.

The science of quality control, although a fast-developing movement in industry, is still a long way from being considered universal practice. There remains much selling, promoting, and educating to be done.

The Society cannot be all things to all people, but we can be the voice of authority and guidance in the science of quality control.

Close scrutiny of the activity records of leading Sections of ASQC will reveal the fact that these Sections are engaged in promoting the science of quality control by sponsoring, or actively conducting, educational programs in quality control that offer training opportunities for various levels of industrial personnel. ASQC must continue and greatly expand this policy.

The Society will continue to grow and prosper as long as it adheres to the purposes for which it was founded.

3. CHARLES L. BRADY

Quality Control Engineer
Milwaukee Gas Specialty Co.

What is a blueprint for modern quality control?

This question has been turning over in my mind for several years. A number of these questions have been answered by Martin A. Brumbaugh's article "Quality Control—Today's Foundation for Tomorrow's Reputation". However, I am glad to see there will be further discussion of a blueprint for modern quality control in our journal.

I believe that statistical control of quality as a part of the Inspection Department function will gradually replace the old style hit and miss inspection functions and will be most successful if the statistical quality control supervisor or engineer maintains the responsibility of supervision of all established functions of statistical control work. Statistical

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QUALITY-CONTROL HANDBOOK

Edited by J. M. JURAN

McGraw-Hill Industrial Organization and Management Series

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J. M. JURAN is consultant on quality control, to leading industrial companies, Professor of Industrial Management at N.Y.U., and author and lecturer. In 1945 he was awarded the Worchester Reed Warner medal by the A.S.M.E. for "outstanding contributions to the problem of quality control in mass production."

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control divides the Inspection Department. If the division is made by the Superintendent of Quality, there can be no question in the minds of other supervision as to the responsibilities of the statistical control department. The passing and rejection of the material which is inspected by statistical control methods remains the responsibility of that department.

This division of the Inspection Department becomes necessary for its future strength because, as we all know, the Inspection Department of many manufacturing plants is the weakest link in the organization. Their hit and miss methods are the direct result of the prohibitive costs of sufficient inspection without the use of statistical methods.

How can healthy growth be accomplished? I believe it can be accomplished best from selective choice of manufacturing processes, one by one, with complete routine control established before going on to the next one, and most naturally, choosing "bread and butter" type of controls first for cost savings impressions on management to insure future growth.

Segments of the Quality Control Department could be assigned the responsibility of presenting statistical data to the Engineering Department for specification changes, making up management control chart summaries, etc. But the big responsibility of controlling quality with authority for action should always remain the largest segment of any Statistical Control Department.

Research Looks At Quality Control*

W. H. LYCAN

Director of Research, Johnson & Johnson

THE function of Quality Control in many American companies has been handled until very recent times as a vaguely integrated activity of the Research Department. It has all too frequently been looked upon essentially as an analytical and testing service with the limited responsibility to report quality data. Interpretation of data and responsibility for action when deviations from specifications occur have been assigned to or assumed by others. These others have been either manufacturing or sales personnel or, more frequently, the two together have resolved between them questions of quality deviation as deviation has occurred.

As one who has been responsible for the administration of a Research Department, I have been interested and impressed with the development of systematic techniques of Quality Control. I have spent too many unhappy hours "in the middle" when there was a divergence of interests on deviation from quality standards not to welcome systematic Quality Control. It has made a vital place for itself in forward-looking manufacturing operations and research men everywhere are happy that it has.

The fact is that a dependable system of measuring performance has been developed which pleases us; perhaps equally important is the minimizing of the personal element. The personal element can never be wholly removed but certainly you have gone far toward that goal in the relatively few years that Quality Control has been recognized as an independent function. No more can there be a distressing difference of opinion between Manufacturing and Sales as to whether or not a manufactured product meets specifications. It does or it does not, and Quality Control has generally attained the stature where it is sole arbiter on that question.

It has attained that stature and will retain it and grow in importance in a measure proportionate to its resistance to the natural pressures that assail it. There is little problem when out-and-out deviations from accepted quality standards occur. It is the recurring borderline deviation that tests the true mettle of a Quality Control Department. It is natural for the manufacturing man to want to call all the close ones strikes and equally natural for the salesman to call them balls. Quality Control must stand resolutely between and, in my opinion, will best serve its company by erring on the side of highest quality.

There is in this situation where the skirting of specifications occurs a lesson which, I presume, is an old one. It has to do with the way in which specifications are originally drawn. The writing of a proper and complete specification on a manufactured and packaged item is not an easy task. When it has been left in the hands of a busy chemist, a manufacturing supervisor, or someone in sales or merchandising, it is likely to be a pretty incomplete document.

In Johnson & Johnson, we have tried to make our specifications as complete and as definitive as possible by having Quality Control responsible for writing them. Naturally, all other departments involved, manufacturing, merchandising, purchasing, research, must approve a new specification or a change in an old one. It is up to Quality Control, however, to see that the language of the specification is clear and that every factor entering into quality is covered, no matter how self-evident it may appear to be. Every year we learn a little bit more about how specifications should be written and every year we reach new levels of common understanding on the maintenance of quality standards.

The importance of a common understanding of specifications cannot be too greatly emphasized. They must, therefore, be wholly realistic. Specifications on finished products must be consistent with those on raw materials. The limitations of the process and of the machinery in which it is conducted must have full recognition. There is no such thing as throwing a high, dark pitch past a manufacturing man and getting him to approve something a process or machine cannot regularly achieve. Similarly, the limitation of normal variations in raw materials, particularly when natural materials are involved, must be recognized.

*Presented at the All-Day Conference on Quality Control, Rutgers University, New Brunswick, N. J., Sept. 16, 1950. Program sponsored by the Metropolitan Section, ASQC, and Rutgers University.

When these rules of the game are violated, there will be trouble for the fellow who is doing the umpiring, the fellow from Quality Control.

Let me urge you never to live with a bad specification: get it changed as quickly as you can and you will find common understanding much easier to achieve. You have gone a long way in this direction and every new step will further ease your job of maintaining quality at the highest practical level.

Common understanding as a basis for the writing and acceptance of specifications is a first step toward common understanding in the whole approach to quality. I remember many years ago an experience which illustrates what can happen when it is missing. I was working at the time for a large and very successful manufacturer of dye-stuffs. It was one of my assignments to supervise the manufacturing aspects of the final standardization of a series of colors sold as aqueous pastes to the dyeing and printing trades.

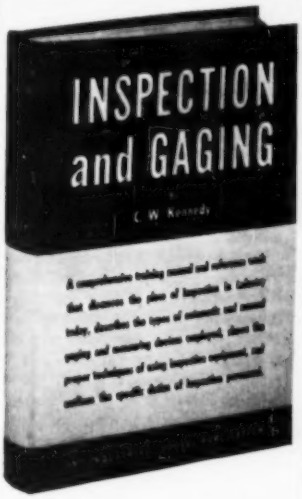
These colors were dispersed by one means or another and converted into colloidal suspensions in water at solids contents ranging from 6-18% by weight. The dispersed pastes were then tested in the laboratory and were adjusted to proper shade and tinctorial strength by comparison against retained standards. The colors thus standardized were approved and were supposed to be shipped against orders to the ultimate consumers.

As a matter of actual fact, what we did was to add 2% of water to every lot after approval. We did this secretly under orders from the area superintendent who sincerely believed than no man alive can grade tinctorial strength within 2% and that the area might as well profit by the two pounds per hundred thus acquired. Since the pastes sold at that time for $1.50 to $4.00 per pound, the theoretical saving was very substantial.

I say theoretical saving advisedly. We never knew it at the time, because both sides had their secrets; but I learned a long time later that the laboratory, knowing about the small but regular loss of strength between approval and shipment, discounted the dilution in advance. In other words, they graded weak and made sure the customer got his money's worth. As a matter of fact, they leaned over backwards to be sure there were no complaints on strength and, in the end, the little trick cost the company money instead of saving it.

This is only one incident where lack of common understanding and a common approach reacted against the interests of a company. It happens every day, in every company, even those blessed with capable Quality Control Departments. The campaign, therefore, for continuing understanding and continuing common effort is a never-ending one. In Johnson & Johnson we expect Quality Control to maintain an almost secularly religious attitude toward the never-ending task of education of those whose work is reflected in day-to-day quality levels. The day that Quality Control becomes self-satisfied is the day that upward trends in quality will be reversed.

There are two other aspects of Quality Control which I should like to discuss briefly. Your day-to-day work, in my opinion, is to see that quality levels reflect the accepted standards which have been agreed upon by all members of your company team. There is little to be gained in needling for quality standards above those required in the specification. If the specification is inadequate, by all means, seek to get it changed but only by and with the agreement of the rest of the team. If, on the other hand, in your zeal for improved quality you succeed in imposing unrealistic standards on a department or a single operation you may be increasing costs out of proportion to the improvement attained. There is another outlet where an excess of zeal can be dissipated to great advantage. As a result of your constant preoccupation with quality, you are peculiarly well-situated to contribute to new developments which improve quality. A major benefit we enjoy at Johnson & Johnson from our Quality Control Department has been its contribution to new developments. Some of these have been along the lines of packaging, some along the lines of product improvement and other on modification or development of machines. Nearly always these are the contributions of people who are capable of projecting themselves into the role of users of the products in question. These are the people who, for the moment, stop looking at the product in detail and look at it as a whole and in the hand of the user. We hope sooner or later in Johnson & Johnson to realize almost as much of a return on



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this phase of the activity of our Quality Control people as we do now on their day-to-day duties. I am happy to say we are well on our way toward that goal.

Finally, there is one other aspect of Quality Control which concerns me and which I suspect concerns many others. American industry is undergoing technological improvement at an unprecedented rate, faster almost than we are socially equipped to digest it. You will no doubt recall the long-term contract reached some months ago between General Motors and the United Auto Workers. There was, in this contract, provision for very substantial wage increases over the next five years in return for which the Union agreed not to oppose technological improvements.

The only way General Motors could possibly justify entering into such a contract was on the basis of increased productivity per man. These increases will come about not by inducing their employees to work harder, but by providing them with better, faster, more efficient machines. Each operator will turn out more units in a given time.

The same thing is happening in almost every industry—it is a part of the system whereby an ever-increasing standard of living is possible. It begins, however, to pose problems of Quality Control. The old-time shoemaker made a quality product without the benefit of Quality Control because he served as his own inspector and critic. When he surrendered his bench for a machine and the machine began to gather speed, he no longer had time to be solely responsible for quality and gradually he shared it with others. Finally, there developed the system of Statistical Quality Control which has served effectively because it has supplemented on-the-job inspection rather than replacing it. It has educated the operator on the job—it has created quality consciousness in him—it has helped him do his job better.

There comes a time, and I suggest that it is not far away in some industries—perhaps it is here—when the operator can no longer be expected to take much part in inspection of the product. It will be up to Quality Control so to adjust procedures and techniques as neither to degrade quality nor to penalize nor alienate the skilled workman. More frequent and more meaningful sampling, more rapid testing and better means of communication with the operator will be required. It will be a more difficult assignment to maintain quality consciousness. It will mean more work for Quality Control.

There is no doubt in my mind that you who are responsible for the quality of so many American products will meet the challenge of technological improvement. I see no evidence of self-satisfaction or professional middle-age in your group or in the program of the American Society for Quality Control. I believe I may speak for all those with responsibility of a technical nature in American industry when I thank you for bringing system into an activity where it was seldom found before the advent of statistical quality control.

Book Reviews

A. C. Cohen, Jr., *Editor*

Correspondence and suggestions concerning book reviews should be sent to:
Professor A. C. Cohen, Jr.
Department of Mathematics
University of Georgia
Athens, Ga.

SOME THEORY OF SAMPLING

William Edwards Deming; John Wiley and Sons, Inc., New York, 1950. XVII, pp. 593. $9.00. Review by W. W. Cooper and D. Rosenblatt, Departments of Economics and Industrial Administration, Carnegie Institute of Technology.

As is well known, some of the best work in statistics, particularly in survey design, has, of recent years, been done in government agencies. This book makes available in one place much of this work which was formerly accessible, if at all, only in scattered articles or government memoranda. It includes not only the work of Washington statisticians but also some of the important contributions of persons such as Yates in England and Mahalanobis in India. With this clear presentation now conveniently available, no statistician can be excused from thorough acquaintance with this work.

Although the book requires close reading, Deming, one of the leaders in this development, has done an excellent job of presentation. Covering the phases of survey design from the planning stage (Chapter one) through elementary definitions of moments and expected values (Chapters 2, 3, and 4), Deming proceeds through multi-phase and multi-stage sampling (Chapters 5 and 6) and allocation in stratified sampling (Chapter 6). The unifying theme in this, the first part of the book, is the matching of cost and administrative requirements against information (in the Fisherian sense) gained. The orientation is toward action and administrative requirements of a type which has received recent fundamental extension by Wald and others in the field of decision theory.

The author is to be congratulated for his emphasis, in Chapter 10 (Estimation of the Precision of a Sample), on post-sampling analysis—i.e., estimating precision of design on the basis of sample results. The book thus conforms to recent recommendations of the U. N. Statistical Subcommission, and adheres to the Subcommission's recommended terminology. Deming follows the logical, if not psychological, approach, developing cluster (multi-stage) sampling prior to treating stratification and associated problems. Systematic sampling is also introduced in its correct logical order, after cluster sampling, but the development of this, probably the most extensively used type of cluster sampling, is not as extensive as could be desired. While mentioning omissions and under-emphases in the book, the following important topics can also be cited: (1) experimental design and analysis of variance as methods of testing hypotheses and designing surveys; (2) interpenetrating sample designs as

means of detecting and controlling bias, enumerator error, response error, etc.; (3) illuminating subsamples, such as those used by the Census Bureau for coverage and quality checks; and (4) order statistics. It is possible that unfolding plans of the publishers, John Wiley and Sons, in the excellent statistical series being developed for them by Dr. Shewhart, will reveal that these topics are scheduled for treatment elsewhere. It would have been advantageous, however, to have them treated in the clear and competent exposition of this volume.

The chief drawback of the book is its price: $9.00; it deserves wider circulation than this price will allow. To this end, the publishers might well give consideration to a new or alternate edition eliminating the last, and mathematical, part of the book, beginning with Part V which covers the Study of Binomial and Related Distributions (Chapter 13), Gamma and Beta Functions (Chapter 14), Distribution of Variances (Chapter 15), Tests for Hypotheses in Normal Theory (Chapter 16) and Distribution of External and Internal Variances (Chapter 17). Not only is this last part of the book presented on a different technical level than the first part, but most of the material is available elsewhere, including treatments by Deming himself. If further reduction is required to bring this book down to a reasonable price for general sale, the two chapters in Part IV—Chapter 11, Inventories by Sampling, and Chapter 12, A Population Sample for Greece—which constitute, essentially, republication of previously published material, might also be eliminated. If a choice must be made it would be better to include some of the topics suggested at the conclusion of the previous paragraph.

But perhaps these recommendations represent counsels of perfection. Nearly every chapter of the book contains something that may be studied with profit, reflecting either Deming's qualities as an expositor or his breadth of experience. Particularly rewarding is the rich array of problems and examples including alternate solutions by various contributors, giving the book a range and freshness which is usually absent in such presentations. Numerous short-cut devices and simplifying suggestions for applied work make this volume a handbook as well as a text.

The book is a must for full-time statisticians. It is unfortunate that the price should prevent its being impressed upon part-time and beginning statisticians as well.

Bibliography

JOSEPH MOVSHIN, Editor

Assisted by the Editorial Committee, St. Louis Section, ASQC

On matters concerning the Bibliography Department, send correspondence, suggestions, and contributions to: Mr. Joseph Movshin, 9220 Old Bonhomme Road, St. Louis 24, Mo.

APPLICATION—CHEMICAL INDUSTRY

STATISTICS SYMPOSIUM (Industrial and Engineering Chemistry, v. 43, n. 6, June 1951) THEORETICAL BACKGROUNDS of the STATISTICAL METHODS — SOME BASIC CONCEPTS OF PROBABILITY AND STATISTICS Henry Scheffé, Columbia University, New York, N.Y. p. 1292.

An outline of certain basic concepts of probability and statistics is attempted without introducing all the detailed mathematics which make the concepts rigorous. The topics included are: probability, distributions, statistical independence, population and sample, sampling distributions, central limit theorem, and states of statistical control.

THEORETICAL BACKGROUNDS OF THE STATISTICAL METHODS — UNDERLYING PROBABILITY MODEL USED IN MAKING A STATISTICAL INFERENCE, Frederick Mosteller, Harvard University, Cambridge, Mass. p. 1295.

This paper was written to explain some important statistical ideas which can help engineering and industrial chemists with everyday problems. The result is a discussion of the notion of testing hypotheses, including such concepts as null hypothesis, significance level, power, and regression.

The ideas presented are common to a large body of statistical theory, and if they are understood the reader will be better equipped both for analyzing the kinds of problems discussed here and for assimilating the statistical theory necessary for tackling more complicated problems of statistical analysis.

DESIGN OF EXPERIMENTS FOR MOST PRECISE SLOPE ESTIMATION, Cuthbert Daniel, New York, N.Y., p. 1298.

The well-known methods for calculating the variance of the slope of a least-square fitted straight line are given briefly, both for constant precision of y measurements and for variable though known precision.

When the relation between two variables is known to be linear, proper choice of x values at which y is to be measured can greatly increase the precision with which the slope is estimated. The gain, compared to the usual N equally spaced points, may be from one third to two thirds of N for a given precision of the slope estimate. This article illustrates how the principles of statistics can be utilized by chemists and chemical engineers to obtain more precise results from their experimental work.

FACTORIAL EXPERIMENTS IN PILOT PLANT STUDIES, J. R. Bainbridge, Imperial Chemical Industries of Australia and New Zealand Ltd., Melbourne, Australia, p. 1300.

The factorial experiment reported in this paper was used to investigate unexpected performance in a small gaseous synthesis plant.

This approach proved applicable and gave convincing and comprehensive information of a kind which had not been obtained in a much longer period of "normal" plant operation.

Of interest to chemical engineers is the detailed examination of the structure of the factorial experiment; the analysis

of covariance; the information obtained, the types of error to which it is subject, and the superior effectiveness of the factorial over other experimental approaches.

CONSTRUCTION AND USE OF STATISTICAL CONTROL CHARTS ON CONTINUOUS VARIABLES, K. A. Brownlee, The Squibb Institute for Medical Research, New Brunswick, New Jersey, p. 1307.

In the control of production processes it is necessary to discriminate between random variation in yield or quality and definite variation assignable to identifiable causes. Attempts to control the former will probably be fruitless, whereas it should be possible to control the latter. The statistical quality control chart, due to Shewhart, is a simple means of making this distinction. Typical random variability of chemical parameters can be approximately represented by the so-called Gaussian curve. The range of a group of observations can be used to give estimates of standard deviation. The reasonable fluctuation of averages can be predicted from a knowledge of the standard deviation of the individuals. Nitrocellulose viscosities and streptomycin assays are used as examples of the procedure. The occasional occurrence of variables with skewed distribution can often be corrected for by the use of the transformation to logarithms.

In addition to the above, this periodical also contains two highly technical articles applying statistics to specific problems.

DROPLET SIZE DISTRIBUTION IN SPRAYS, R. A. Mugele and H. D. Evans, Shell Development Co., Emeryville, Calif., p. 1317.

FITTING BIMODAL PARTICLE SIZE DISTRIBUTION CURVES, J. M. Dallavalle, C. Orr, Jr., and H. G. Blocker, Georgia Institute of Technology, Atlanta, Ga., p. 1377.

APPLICATION—ELECTRICAL INDUSTRY

THE VARIATION IN ELECTRICAL PROPERTIES OF SILICON-IRON TRANSFORMER SHEET, S. Rushton, M. A., B. Sc., D. I. C., Imperial College, London; and D. R. G. Davies, B. Sc., A. I. M., Chief Metallurgist at the Redbourn Works of Richard Thomas and Baldwins, Ltd.
(Journal of the Iron and Steel Institute, v. 167, part 3, March 1951)

This study of the variation in iron-loss values of sheets produced from a single cast of silicon-iron transformer sheet is based on 264 values from 11 ingots of the cast, and on iron-loss values of all the sheets produced from one particular ingot. The statistical technique of analysis of variance has been used to show the contributions to the total variation among these values due to differences between ingots, variation due to different positions in an ingot, and variation due to differences in the position of the sheet in the pack at the sheetrolling stage. The effect of a second anneal has been studied, using the analysis of covariance technique. Causes of the variation in iron-losses are discussed.

TWO NUMERICAL INDEXES EVALUATE MASSES OF METER TEST DATA, F. H. Busch. Section Engineer, General Electric Company, Lynn, Mass.
(Electrical World, v. 134, n. 25, Dec. 18, 1950, pp 84-86)

Numerical average and standard deviation afford basis for comparing meters as to type, prior test, and service results as well as testing differences in shop, field and division.

APPLICATION—METALLURGICAL INDUSTRY

QUALITY CONTROL FOR THE FOUNDRY, Robert J. Feltrin, Dominion Engineering Co., Ltd., Montreal, Canada.
(Canadian Metals, April, 1951)

Statistical control determines optimum operating conditions and gives immediate warning of any deviation from them.

APPLICATION—MISCELLANEOUS

THE APPLICATION OF STATISTICS TO PHOTOGRAMMETRY, John C. Sammi, New York State College of Forestry, Syracuse, N. Y.
(Photogrammetric Engineering, v. XVI, n. 5, Dec. 1950, p. 681)

Mr. Sammi suggests the application of statistics to certain problems of Photo Interpretation. It is when differences are too fine to classify sets of values by observation that it is desirable to use statistical analysis. Without going into the details of mathematical statistics, illustrations of useful statistical techniques are presented along with problems that might lend themselves to statistical interpretations.

CONTROL CHARTS

MAKING A QUALITY AUDIT OF MANUFACTURING OPERTIONS, C. W. Kennedy.
(Modern Machine Shop, v. 24, n. 2, July 1951, p. 132)

A detailed discussion of the construction and use of the $\overline{X}$ and R control chart and of the interpretation of control chart data. Emphasis is on machine capability related to product specifications.

ENGINEERING & EXPERIMENTS

NEW EDUCATIONAL REQUIREMENTS IN EXPERIMENTAL METHODS, W. L. Gore, E. I. DuPont de Nemours and Company, Wilmington, Delaware.
(Journal of Chemical Education, v. 27, n. 8, Aug. 1950, pp. 419-421)

The place of statistical concepts in the scientific method. This is illustrated by comparing the classical method of testing, changing one variable at a time, with a statistical design, the factorial. The measure of interaction or "preferential responses" found between the variables by using factorial design gave a more complete and valid result.

EVALUATION OF THREE IRON METHODS USING A FACTORIAL EXPERIMENT, L. K. Reitz, A. S. O'Brien, T. L. Davis, Paper Service Department, Eastman Kodak Company, Rochester, New York.
(Analytical Chemistry, v. 22, n. 12, Dec. 1950, pp. 470-1473)

The classical method of designing experiments for testing the precision of an analytical method is contrasted with Fisher's factorial design technique. The advantages of the latter procedure from the point of view of economy of experiments and the detection of interactions are presented. The application of an analysis of variance to data obtained by a factorial experiment

is discussed. These statistical techniques are illustrated by a study of three colorimetric methods for iron-phenanthroline, thiocyanate, and sulfide.

MANAGEMENT & PERSONNEL

QUALITY CONTROL . . . IT WORKS IN SMALL PLANTS, TOO, John S. Morgan, Associate Editor.
(Steel, v. 129, n. 3, July 16, 1951, p. 74)

A very short description of the development and gains of the Lundberg Screw Products Co. quality control program. The need for patience and adapting quality control to the needs of the company are stressed.

MODERN QUALITY CONTROL, A. V. Feigenbaum, Aircraft Gas Turbine Divisions, General Electric Company, West Lynn, Mass.
(General Electric Review, v. 54, n. 4, April 1951, p. 30)

In this general article the following are discussed:

Origins of Present-Day Interest in Modern Quality Control.
What is the Definition for Quality Control?
What is New About Quality Control?
What is a Quality Control Program?
Is Quality Control Good Only for Mass Production?
How do Statistics Relate to Modern Quality Control?
Are Statistics the Only Quality Control Technical Method?
What is the Organization for Quality Control?
How Should a Modern Quality-Control Program be Introduced?
What Benefits May be Obtained from Modern Quality Control?

SAMPLING PLANS & RELATED TOPICS

STREAMLINING ACCEPTANCE INSPECTION — NEW MILITARY SAMPLING TABLES STANDARDIZE EVALUATION PROCEDURE, Dr. William R. Pabst, Jr., Quality Control Division, Navy Bureau of Ordnance.
(Ordnance, v. 35, n. 185, Section 1, March-April 1951, pp. 485-488)

A general description of the new MIL. STD. 105A "Sampling Procedures and Tables for Inspection by Attributes" and the improvements over JAN. STD. 105.

THEORY & APPLICATION—GENERAL

SIMPLIFIED STATISTICS FOR SMALL NUMBERS OF OBSERVATIONS, R. B. Dean and W. J. Dixon, University of Oregon, Eugene, Ore.
(Analytical Chemistry, v. 23, n. 4, April 1951)

Several short-cut statistical methods can be used with considerable saving of time and labor. This paper presents some useful techniques applicable to a small number of observations. Advantages of the median as a substitute for the average are discussed. The median is especially useful when a quick decision must be made and gross errors are suspected. The range may be used to estimate the standard deviation and confidence intervals with little loss in precision for small numbers of observations. A convenient criterion for rejecting gross errors is presented. A table gives efficiencies and conversion factors for two to ten observations. The statistical methods presented are sufficiently simple to find use by those who feel that "statistics are too much trouble." These methods are usually more exact than the statistics of large numbers applied directly to small numbers of observations.

STATISTICS

STATISTICS OF CORRELATED EVENTS, C. Domb, Clarendon Laboratory, Oxford.
(Philosophical Magazine, v. 41, n. 321, Oct. 1950, p. 969)

THE EFFECTIVENESS OF QUALITY CONTROL CHARTS, Leo A. Aroian, Hunter College, & Howard Levene, Columbia University.
(Journal of the American Statistical Association, v. 45, n. 252, Dec. 1950, p. 520)

PROPERTIES OF SOME TESTS IN SEQUENTIAL ANALYSIS, A. G. Baker.
(Biometrika, v. 37, Dec. 1950, p. 334)

PRESENT STATUS OF VARIANCE COMPONENT ANALYSIS, S. L. Crump, p. 1.

TESTING A LINEAR RELATION AMONG VARIANCES, W. G. Cochran, p. 17.

CONSISTENCY OF ESTIMATES OF VARIANCE COMPONENTS, R. E. Comstock and H. F. Robinson, p. 75.

VARIANCE COMPONENTS AS A TOOL FOR THE ANALYSIS OF SAMPLE DATA, W. A. Hendricks, p. 97. (Biometrics, v. 7, March 1951)

Additional works on analysis of variance are included with these.

AN APPLICATION OF DETERMINATES TO THE PROBABILITY OF MATED PAIRS, Julia W. Bower, Connecticut College.
(The American Mathematical Monthly, v. 58, n. 4, April 1951, p. 238)

AMERICAN SOCIETY NEWS

SOCIETY GENERAL COMMITTEES

With the addition of so many Sections to our Society the original plan of operation of these five committees became too cumbersome for them to function effectually. In prior years, each Section appointed a representative to each committee. A Regional Chairman was then selected from among the appointees from the Sections within each Region, and the General Chairman attempted to function through these Regional Chairmen. With over forty Sections involved (forty-nine at present), this was much too time-consuming; hence, a new policy has been adopted.

The individual Committee Chairmen have selected a committee of appropriate size in each instance, and this group will function as a committee, their respective contacts with the various Sections of the Society being through the Vice Chairmen of the Sections. These committees will apportion their work as seems advisable in each case.

Recommendations having been received and duly approved by the Executive Committee, these five Society General Committees are presently constituted as follows:

Membership

Chairman: Robert S. Inglis, Philadelphia; *Vice Chairman:* Elbert T. Terhune, Indianapolis. Harold L. Hamilton, Hartford; Leonard E. Coger, Rochester; Harmon S. Bayer, Michigan; Jack A. Riegert, St. Louis; David E. Moosman, San Francisco; and Michael A. O'Hanlon, Jr., Philadelphia.

Program & Speakers

Chairman: John G. Rutherford, Baltimore; *Vice Chairman:* Paul A. Robert, Southern Tier. Charles A. Bicking, Delaware, and Henry J. Jacobson, Chicago.

Education & Training

Chairman: A. C. Richmond, Chicago; *Vice Chairman:* John A. Henry, Central Illinois. Frank E. Satterthwaite, Southern Connecticut; Andrew Schultz, Jr., Southern Tier; Samuel P. Owen, Metropolitan; Max Astrachan, Dayton; and Eugene L. Grant, San Francisco.

Publicity & Promotion

Chairman: John F. Occasione, Cleveland; *Vice Chairman:* E. H. Robinson, Chicago. Clifford W. Kennedy, Rhode Island, and Frank Caplan, Jr., Syracuse.

Technical Societies

Chairman: Dr. Julian H. Toulouse, Toledo. M. E. King, Washington; A. H. Croup, Erie; I. Glenn Stevenson, Southern Tier; Edward Cartotto, Los Angeles.

Additional members may be added to these Committees as conditions dictate. Mr. Simon Collier, Vice President, has been assigned by the President the chore of coordinating the activities of these five committees, and integrating their efforts.

COMMITTEE APPOINTMENTS

The President has appointed Dr. Julian H. Toulouse, Chief Engineer of the Quality and Specifications Department of the Owens-Illinois Glass Company, Toledo, Ohio, as special Assistant to the President to act as special coordinator of the Society's various Technical Committees. This is a complicated field and involves certain long range policies of the Society; hence, merits the specialized attention thus accorded it.

Shewhart Medal

According to the rotational plan in effect, the terms of service of three members of this Committee expired on June 30, 1951. The Society is deeply indebted to G. Rupert Gause, J. Frederick Verigan, and A. E. R. Westman for their helpful cooperation and service on this Committee.

The President has invited Harold F. Dodge, Martin A. Brumbaugh, and J. Clayton Knapp to serve three year terms beginning July 1, 1951, to replace the above retiring members.

Brumbaugh Award

Members of this Committee serve a term of four years, two retiring each year. The terms of Joseph J. Ferri and Wyatt H. Lewis expired June 30, 1951, and these are replaced by Irving W. Burr and John A. Henry, at the invitation of the President, to serve until June 30, 1955. The Society herewith expresses its sincere appreciation to the retiring members for their valuable assistance.

Nominating Committee

The Executive Committee has approved the appointments of members to this Committee from the Middle Atlantic and Northern Regions. Since the terms of office as National Director of the other members of this Committee are still effective, those individuals will continue as members of the Committee. The complete roster is, as follows:

Chairman—Ralph E. Wareham

Dorian Shainin—*New England Region*

Enoch B. Ferrell—*Middle Atlantic Region*

I. Glenn Stevenson—*Northern Region*

Ralph A. Hefner—*Central Region.*

A. C. Richmond—*Mid-West Region.*

Wyatt H. Lewis—*Western Region.*

The Nominating Committee has received its instructions from the President, will prepare for the election of three Vice Presidents for the ensuing fiscal year in accordance with the Constitutional Amendment approved by the Board of Directors and ratified by the Members at the last annual balloting, and will report to the Executive Secretary on its recommendations as prescribed by the Constitution. Its report will be published in the next immediate issue of Industrial Quality Control or the News Supplement, whichever printing deadline can be met, following receipt of the report by the Executive Secretary.

General Convention Committee

Regret is expressed at the receipt of the resignation of Robert E. Wagenhals as a member of this Committee, and also as Assistant Advertising Manager. The Executive Committee has appointed Charles R. Kendel, Cleveland, to serve on the Convention Committee, his specific assignment being that of Exhibits.

Examining Committee

Lloyd A. Knowler, Chairman, announces the appointment of Robert S. Inglis, Philadelphia, to fill the vacancy created by the automatic retirement of Martin A. Brumbaugh. The Society owes a debt of gratitude to Dr. Brumbaugh for the guidance he has provided in this important field and for the untiring interest, so characteristic of all his Society connections, which he has devoted to the subject. Mr. Inglis will serve a five-year term ending June 30, 1956.

Auditing Committee

The election of Paul Robert to the office of Treasurer of the Society has reacted unfavorably on his eligibility to membership on this Committee. Clarence R. Burdick, Michigan, has been appointed by the Executive Committee to fill the vacancy thus created.

The names of other members of these foregoing committees may be found by referring to the Year Book.

SHEWHART MEDAL FUND

Members will recall that the original fund to implement the creation of this medal was raised by popular subscription under the leadership of P. L. Alger. This fund of some $1,800 provided for the art work, making of the dies, and casting of the initial medals. The Treasurer, when making his annual report to the Board of Directors on May 25, 1951, mentioned that the fund was practically exhausted and pointed out the desirability of perpetuating this medal award by endowment.

The following letter has been received by the President:

Mr. Wade R. Weaver, President
American Society for Quality Control
Dear Wade:

It has come to our attention that the Shewhart Medal Fund has become dangerously depleted. Unquestionably the National Society's financial condition is strong enough at present to prevent an interruption in the continuity of presentation of this medal. However, in consideration of the fact that the Shewhart Medal Award has been established in honor of the illustrious fiunder of the modern science of Quality Control, Dr. Walter A. Shewhart, and in consideration of the fact that the award is made to honor individuals

who have made outstanding contributions toward the advancement of Quality Control, it does not seem fitting that the perpetuation of this award should be dependent upon the varying status of the Society's General Fund.

The significance of the Shewhart Medal Award is such that everyone interested in Quality Control should be interested in preserving and in participating in such a means for recognizing and honoring individuals who by their creative efforts advance the cause of Quality Control.

In order that future presentations of this award may be independently financed and its continuity thus reasonably assured, the Executive Committee of the Cleveland Section has authorized me to forward to you the accompanying check for $75.00 for the establishment of a fund for this specific purpose. It is our sincere hope that other Sections of our Society will see fit to augment this fund to the point that the income derived therefrom will be adequate to defray expenses involved in the annual presentation of the Shewhart Medal Award.

Sincerely,
John F. Occasione, Chairman
Cleveland Section

The Officers and Directors of the Society herewith express their most sincere appreciation and thanks to the Cleveland Section for its generous gift, as well as the thought behind the action. With this as an inspirational start, it is hoped that a fund of $2,000 can be raised to provide an investment, the income from which will defray the annual cost of the award. Contributions from individuals, or groups, who wish to participate in this endowment will be most gratefully received.

Another very generous offer to this same cause has been made by the Metropolitan Section which has agreed to make an annual contribution to the fund of an amount substantially equivalent to the annual medal presentation cost. The Society also wishes to gratefully acknowledge this splendid evidence of keen interest, and to commend the Officers and Directors of the Metropolitan Section for their generous thoughts and action.

BOARD OF DIRECTORS

The term of office of a National Director is two years, the terms of the Directors from half the Section expiring each year. The following Sections had Directors' terms expiring June 30, 1951: Baltimore, Birmingham, Boston, Cleveland, Columbus, Delaware, Erie, Hartford, Indianapolis, Los Angeles, Metropolitan, Michigan, Mid-Hudson, Minnesota, Montreal, New Hampshire, Parkersburg, Philadelphia, Rochester, San Francisco, South Texas, Southern Connecticut, Syracuse, and Western Massachusetts. In addition, the Directors from the Buffalo and Northeastern Indiana Sections tendered their resignations effective that same date. These Sections having selected their Directors to represent them for the ensuing period ending June 30, 1953, the Board of Directors of the Society is now composed as follows:

President: Wade R. Weaver
Vice President: Simon Collier
Secretary: Alfred L. Davis
Treasurer: Paul A. Robert
Jr. Past President: Ralph E. Wareham
Chairman, Editorial Board: Mason E. Wescott

New England Region

Boston: Louis Rosenblum
Hartford: Dorian Shainin
New Hampshire:
Rhode Island: Roy G. Volkman
So. Connecticut: Welton D. Parker
Western Mass.: Gerald H. Cassady

Northern Region

Buffalo: Edward J. Young, Jr.
Mid-Hudson: William Bobalke
Montreal: B. K. Lloyd
Rochester: Joseph C. Warren
Southern Tier: I. Glenn Stevenson
Syracuse: Leon Bass
Toronto: R. J. D. Gillies
Univ. of Western Ontario: M. Fred Kennedy

Middle Atlantic Region

Baltimore: Besse B. Day
Delaware: Henry T. Clark
Lansdale: F. C. Schulze
Metropolitan N. Y.: Enoch B. Ferrell
Philadelphia: Joseph E. Beezer
Washington, D. C.: Churchill Eisenhart

Central Region

Birmingham: Wm. F. McCartney
Cincinnati: Maurice Rosenblatt
Cleveland: S. C. Bates
Columbus: R. E. Wagenhals
Dayton: Max Astrachan
Erie: J. Stuart Zahniser
Georgia: Ralph A. Hefner
Greater Muskegon: Charles A. Lutrey
Michigan: William H. Smith
Parkersburg: William J. Chelgren
Pittsburgh: Harold L. Springer
Tennessee: T. R. Bainbridge
Toledo: Julian H. Toulouse

Mid-West Region

Central Illinois: A. C. Richmond
Chicago: Henry J. Becker
Denver: Dale L. Lobsinger
Indianapolis: George W. McDermott
Iowa: F. J. Halton, Jr.
Milwaukee: Raymond S. Saddoris
Minnesota: Philip O. Lysne
Muncie: James W. Fodrea
N. E. Indiana: Keith Ross
Racine: Samuel E. Peters
Rock River Valley: Carl A. Samuelson
St. Louis: Cameron E. Fisher
South Texas: B. L. Cloud

Western Region

Los Angeles: Wyatt H. Lewis
San Francisco: Dorothy L. Biggs
Seattle: Charles E. Ellis

EXECUTIVE COMMITTEE 1951-52

New Regional Directors having been duly chosen to succeed all those whose terms as National Directors have expired, the Executive Committee of the Society is now complete and is constituted as follows:

Chairman
Wade R. Weaver, *President*
Simon Collier, *Vice President*
Secretary
Alfred L. Davis, *Executive Secretary*
Junior Past President
Ralph E. Wareham
Treasurer
Paul A. Robert
Chairman, Editorial Board
Mason E. Wescott
Regional Directors
Dorian Shainin—*New England*
Besse B. Day—*Middle Atlantic*
I. Glenn Stevenson—*Northern*
Max Astrachan—*Central*
Raymond S. Saddoris—*Midwest*
Dorothy L. Biggs—*Western*

The new Executive Committee held its first meeting in New York City on Saturday and Sunday, September 8 and 9, 1951. Important action taken at that meeting is reported below.

New Sections Admitted

Newest Section outside the United States is Section No. 50, Mexico City, which, with three in Canada, brings this total to four. This Section has tentatively been placed in the Western Region. Section No. 51 is Wichita, Kansas, bringing the total of Mid-Western Region Sections to fourteen. The New England Region now has a total of seven Sections

with the admittance of the Buzzards Bay Section, covering the New Bedford-Taunton-Fall River, Massachusetts area. Another Section has been added to the rapidly developing South with the addition of Huntsville, Alabama, giving the Central Region fourteen Sections. The Society now has a total of fifty-three Sections. Several more are in the formative stages.

The Society wishes to welcome the officers, directors, and members of the above new Sections, and expresses the hope that they will call upon us for such assistance as they may need in building strong, active Sections. Their inclusion in our ever-growing family is most welcome.

Information Folders

Following necessary revisions to bring this piece of publicity matter up-to-date, a new printing was authorized. These should be available to Sections about October first.

Convention Fund

A Convention underwriting fund of $6,000 was established, from the proceeds of the Cleveland Convention, to serve as an "insurance" fund for any losses which might be sustained on future National Conventions.

1951-1952 Budget Adopted

The President's budget, anticipating an income of $44,566 (exclusive of Sixth National Convention) and expenses of $40,080, was approved and adopted.

National Conventions

The status of future Convention sites and dates was reviewed as follows:

1952—Syracuse, New York—May 22, 23, 24—Memorial Auditorium.
1953—Philadelphia, Pa.—May 27, 28, 29—Convention Hall.
1954—St. Louis, Mo.—June 9, 10, 11—Kiel Auditorium.
1955—New York City, N. Y.—Dates and Site to be selected.

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

Management Controls

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POSITION WANTED

Address all replies to box number references to: American Society for Quality Control, Room 5036, 70 East 45th Street, New York 17, N.Y.

QUALITY CONTROL ENGINEER. Age 37. Six years Quality Control experience in the electrical, mechanical, and chemical industries. Engineering and statistical degrees. Nationally known; many speeches and publications. Qualified for manager of Inspection and Quality Control or as engineer in large inspection, test, or research organization. Salary range: $10,000. Please reply to 8C1 at above address.

POSITIONS AVAILABLE

Address all replies to box number references to: American Society for Quality Control, Room 5036, 70 East 45th Street, New York 17, N.Y.

JOB TITLE: Inspection Specialist (Quality Assurance)
SALARY: $6400.00 per annum
ORGANIZATION: Quartermaster Inspection Service, U. S. Army
LOCATION: New York City
DUTIES: To develop procedures for inspection operations and in particular for use of sampling plans, both variables and attributes
QUALIFICATIONS: Thorough knowledge of mathematical statistics and responsible experience in inspection operations (Government or private industry)
CONTACT: David H. Schwartz
QM Inspection Service National Office
111 East 16th Street
New York 3, New York
SPring 7-4200, Ext. 36

QUALITY ENGINEER—Graduate E. E., to act in advisory capacity for Quality Control Department. Duties involve determination of quality problems which can be expected to occur in manufacturing process. Applicant needs background of experience in product control and electronic component manufacture. Write to 8J1 at above address.

QUALITY CONTROL ENGINEER—Recent graduate engineer. Prefer some training or experience in use of statistical quality methods. Write to 8J2 at above address.

ELECTRICAL STANDARDS ENGINEER—Graduate engineer with work experience in electrical-mechanical measuring laboratory. Position will involve set-up of qualification systems to determine and maintain accuracy of production measuring equipment. Supervisory responsibility for Jr. Quality Control personnel. Write to 8J3 at above address.

QUALITY CONTROL ENGINEERS—Immediate openings at Connecticut and Arkansas plants for experienced Quality Control Engineers. Qualified applicants having mechanical or electrical engineering degree plus training and practical experience in statistical quality control. State educational background, experience, date available, locale preferred, and salary required in resume to 8J4 at above address.

REQUEST TO AUTOMOTIVE INDUSTRIES

The Automotive Technical Committee, ASQC, is maneuvering into a position where it can be of service to the automotive industry by handling requests for technical literature on quality control applied in the automotive field. Building an adequate file of case histories is a big project. We are, therefore, requesting automotive manufacturers and their suppliers to contribute as many case histories as possible.

Please send all literature to:
W. H. Coughlin, Thompson Products, Inc.
23555 Euclid Ave., Cleveland 17, Ohio

NOTICE

Membership lapel badges are now available as follows:

Grade of Membership	Badge	Price
Member	Sterling Silver	$1.75
Senior Member	10 K Gold	$3.75
Fellow	10 K Gold with Sapphire	$4.75
Honorary Member	10 K Gold with Diamond	....

All the above prices include Federal Excise Taxes. Badges may be purchased *only* through local Section Secretaries except for Members-at-Large who may order badges through the Executive Secretary.

UNSURPASSED INSPECTION VERSATILITY

PRODUCTION INSPECTION ON THE SPOT

TOOLROOM CHECKING OF EVERY KIND

LABORATORY GAGING WITH SPEED AND PRECISION

With Jones & Lamson Optical Comparators

★ They meet the requirements of toolroom, laboratory and production inspection.

★ They precisely measure height, depth, lead or spacing, as well as angles to degrees and minutes.

★ They compare intricately contoured parts with a master outline – and measure the amount of error.

★ They are convenient to operate, easy to set up and read direct – without computation.

★ They will photograph the enlarged shadow and record its relationship to a master chart.

★ They will operate under normal lighting conditions. No dark room is needed.

★ Several persons may study the shadow at the same time.

★ They will inspect and measure surfaces, as well as profiles, of objects such as type faces, stamping dies, punches, worn tools, etc.

Jones & Lamson Optical Comparators are built in many models and sizes. We shall be glad to send catalog giving full details. Better yet, send us parts or prints with a description of your measuring and inspection problems – we shall be pleased to help.

Optical Comparator Division

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Springfield, Vermont, U.S.A.

Machine Tool Craftsmen Since 1835

Electricator Multi-Dimension Gage

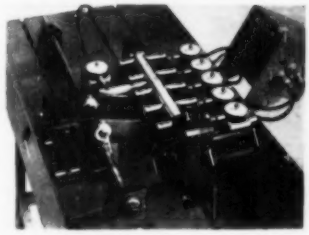
....ONE *QUICK* LOOK TELLS ALL!

Whether it's shells or shafts, fuses or jet engine blades—whether it's two, or twelve, or more dimensions you can tell at a single glance if all are within tolerance or not; for diameter or concentricity, and for length or any other dimension. You can also find out quickly *how much* any dimension is "off" so you can save and classify oversize pieces for reworking.

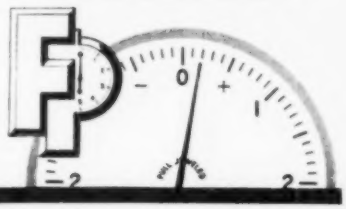
This is possible because the Federal-Electricator units which gage each dimension combine the advantage of the Dial Indicator graduations with electrical tolerance contacts. If any dimension is wrong its identity is immediately flashed on the light panel. The Dial Indicator graduations also make it easy to set the Gage to size limits. A pilot light tells you at all times that the Gage is in working condition.

Anything from small pieces to large can be gaged. Some Electricator Multi-Dimension Gages are made adjustable for various sizes (see photo below). Large pieces are lifted in or out by either hand or foot-operated lifting arms as shown in illustrations.

Tell us about your requirements, and let us figure out the Gage that will tell you what you want to know quickly and positively. FEDERAL PRODUCTS CORP., 1511 Eddy St., Providence 1, Rhode Island.



This Electricator Gage is adjustable for workpieces of various diameters and lengths. Notice a single monitor light signals when any dimension is "off".

FEDERAL

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